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Circular No. 720

# CONTROLLING INSECTS IN FLOUR MILLS

R. T. COTTON, Senior Entomologist
J. C. FRANKENFELD, Entomologist
Bureau of Entomology and Plant Quarantine
Agricultural Research Administration
and G. A. DEAN, Entomologist
Kansas Agricultural Experiment Station

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THE HIGH standards of modern times demand that food supplies reach the consumer in perfect condition. The problem of manufacturing flour and preserving it in an insect-free condition is complicated by the fact that grain, the raw product, is invariably infested when it reaches the mill.

Wheat can be maintained free from serious insect infestation by proper storage on the farm or in the elevator and by the judicious use of high or low temperatures or fumigation. After it reaches the mill, cleaning operations and centrifugal force can be employed to free it of insects likely to contaminate the mill.

Practical methods of ensuring the production of insect-free flour include holding the insect population in the mill at a low level by sanitation, periodic general mill fumigations or heat treatments, supplemental local fumigation of milling units, and finally, treating the finished flour by centrifugal force or redressing it by means of a sifter.

After manufacture, flour must be protected from insect infestation by packaging it in clean or insect-proof bags, storing it under sanitary conditions apart from other infested or susceptible foodstuffs, and transporting it in insect-free conveyances.

This circular discusses the many methods proved useful in preventing insect infestation in flour during the process of manufacture and subsequent handling. It is a revision of and supersedes Circular 390, Flour-Mill Insects and Their Control.

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# Controlling Insects in Flour Mills

By R. T. Cotton, *senior entomologist*, and J. C. Frankenfeld, *entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration*, and G. A. Dean, *entomologist, Kansas Agricultural Experiment Station*

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## INTRODUCTION

The losses caused by insects injurious to stored grain and milled products are tremendous. It is estimated that in the United States alone these losses amount to at least $300,000,000 annually, and this does not take into consideration the reputations of the milling company, the flour broker, and the baker, which suffer when their well-established brands of products are damaged by the presence of insects.

The present-day practice of storing flour for long periods makes it necessary not only to provide protection from insect invasion while it is in storage but also to see that it is so manufactured, packaged, and delivered that it is free from insect life when it is placed in storage. The presence of insects or their excrement in flour is considered to render it unfit for human food, and flour so contaminated is liable to seizure if it enters interstate commerce.

Stored grain and milled cereal products are fed upon by a large group of insects that have adapted themselves to a diet of dried vegetable material. Some of these insects breed almost exclusively within the kernels of grains and are of importance to the miller only as destroyers of the raw unprocessed grain. Others do little damage to whole grain but are extremely destructive to milled cereal products and cause great concern when they become established in the flour mill. A knowledge of the more important insect pests of both grain and milled cereal products will aid in a proper understanding of the problems involved in preventing losses from their activities.

## INSECT PESTS OF STORED GRAIN[1]

Of the many kinds of insects found associated with supplies of stored grain only a few cause serious damage. The rice weevil (*Sitophilus oryza* (L.)) (fig. 1), the granary weevil (*S. granarius* (L)) (fig. 2), and the lesser grain borer (*Rhizopertha dominica* (F.)) (fig. 3) are the worst offenders. These insects are capable of boring into sound grain, and their initial attack opens the way for others that are unable to cut their way through the tough seed coat. The immature stages of these beetles live almost exclusively within the kernels of grain and, although the larva of the lesser grain borer is free-living and all three

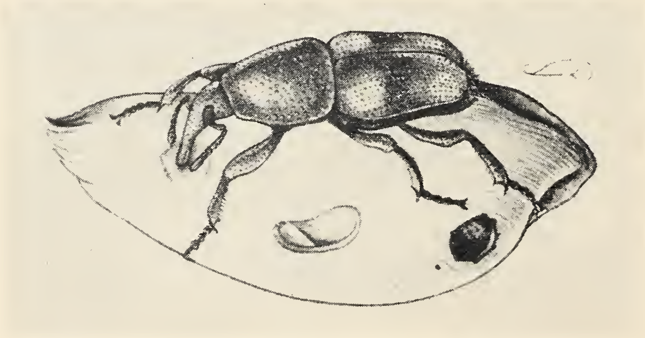

FIGURE 1.—The rice weevil, one of the worse pests of stored grain.

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[1] For more detailed information regarding the insect pests of stored grain and its products, see the following publication:
BACK, E. A., and COTTON, R. T. STORED-GRAIN PESTS. U. S. Dept. Agr. Farmers' Bul. 1260, 46 pp., illus. 1940. (Revised.)

species are capable of breeding in caked, solidified, or closely packed flour, they cannot be considered important pests in the flour mill itself.

In some sections of the country the Angoumois grain moth (*Sitotroga cerealella* (Oliv.)) (fig. 4) is a serious pest in wheat before it is threshed and binned, but its damage to grain in elevator storage is negligible. Infestations of a number of other species of moths sometimes occur on the surface of bins of grain, and a matting of silk spun by the larvae, or worms, of these moths sometimes covers the entire surface. Injury from these insects seldom extends far below the surface because the moths themselves are unable to force their way into the binned grain to lay their eggs.

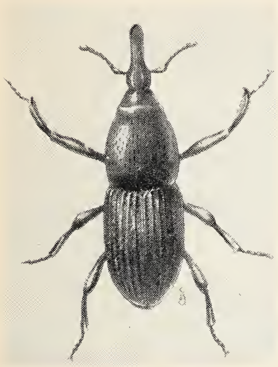

FIGURE 2.—The granary weevil, unable to fly, yet frequently found infesting stored grain.

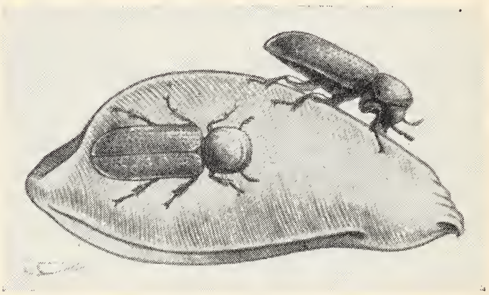

FIGURE 3.—The lesser grain borer, which in recent years has become common in many parts of the country in both elevator- and farm-stored wheat.

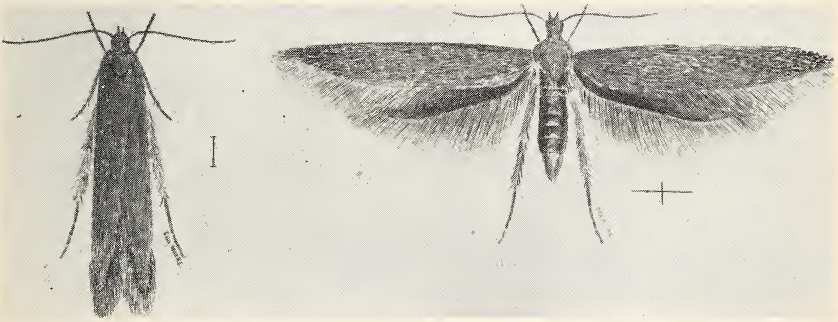

FIGURE 4.—The Angoumois grain moth, which attacks grain both in the field and in storage.

A number of species of beetles that are not primary pests of stored grain, but that feed on broken grain, grain dust, or grain damaged by the true weevils, or borers, are sometimes of considerable importance, not only because of the damage caused by their feeding but also because the activities of large numbers of these insects may cause heating and an increase in the moisture content of the grain with consequent spoilage of portions of it. They are referred to as bran beetles or bran bugs. The more important of these are the confused flour beetle (*Tribolium confusum* (Jacq.-Duv.)), the red flour beetle (*T. castaneum* (Hbst.)), the flat grain beetle (*Laemophloeus minutus* (Oliv.)), and the saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)).

## INFESTATIONS ON THE FARM AND THEIR CONTROL

Infested grain used by the miller for milling purposes is one of the important sources of insect infestation in the mill. Much of the infestation in stored grain originates on the farm. The rice weevil and the Angoumois grain moth may infest grain, not only when it is in the shock or stack in the field but also before it is harvested. Particularly in the South, large numbers of these insects fly from grain cribs and bins when the grain begins to ripen in the fields. The eggs that are laid in or on the grain at this time develop into weevils or moths, giving rise to the common but erroneous belief that they are inherent in the germ of grain.

After the grain has been harvested, threshed, and placed in bins on the farm, it may be further infested. Many seemingly clean and empty bins may actually harbor thousands of hungry insects. The larvae of the cadelle (*Tenebroides mauritanicus* (L.)) burrow in the woodwork of bins in enormous numbers and may remain there for long periods, only to come out when fresh grain is placed in the bin. Dust seeps into these burrows, and other types of insects use the burrows for temporary living quarters. It is not uncommon to see newly threshed grain literally swarming with worms a few weeks after it had been placed in wooden bins.

A common practice on the farm is to store bran, shorts, and other milled feeds in the granary. Occasionally cleanings from mills, sweepings, or damaged or infested flour and meal may be purchased as cheap sources of feed. These products may harbor large numbers of bran beetles, which sooner or later migrate to bins of new grain.

By encouraging the proper storage and care of grain on the farm, the miller will not only help the wheat grower to avoid losses but also will ensure for himself a supply of grain that will require less attention and cause less trouble after it reaches the mill.

### GRAIN SHOULD BE KEPT DRY AND COOL[2]

If sufficiently dry and cool, grain can be stored without danger of insect damage. Grain-infesting insects are not active at temperatures below 40° F. and do not breed actively until temperatures above 70° are reached. It has been observed that in States north of latitude 40° N., in the hard winter wheat region, stored wheat that enters the winter in good condition can be expected to cool down to temperatures in the low 40's even in the southern part of this region; and if stored in steel bins of 2,000-barrel capacity or greater, the average temperature of the grain in the bin will rise above 70° for only a short time during the year. If the grain is reasonably dry and clean, little damage need be feared from insect attack when it is stored under these conditions.

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[2] For sugestions for cleaning and drying wheat consult the following publications: UNITED STATES AGRICULTURAL ADJUSTMENT ADMINISTRATION. WHEAT STORAGE ON THE FARM AND IN THE EVER-NORMAL GRANARY. U. S. Agr. Adjustment Admin. G–106, 57 pp., illus. 1941.

KELLY, C. F. METHODS OF VENTILATING WHEAT IN FARM STORAGES. U. S. Dept. Agr. Cir. 544, 74 pp., illus. 1940.

If temperatures are normal, most grain-infesting insects are unable to breed in clean grain with a moisture content below 11 percent. The granary weevil, however, has been observed to breed at a temperature of 70° F. in grain containing 10 percent of moisture; and if the temperature of the grain is 90°, both bran beetles and weevils will reproduce in grain with a moisture content as low as 9 percent. In grain containing 12 percent of moisture both the granary weevil and the rice weevil lay eggs at 60°. Larval development is slow at these temperatures. During the hot summer months the temperature of the grain on the surface of all bins and next to the walls of steel bins is high, therefore localized infestations of bran beetles may flourish. These infestations normally do not spread through the bin if the bulk of the grain is cool. In the southern part of this region greater care must be taken of wheat stored in small bins, owing to the greater rapidity with which temperature changes occur and the longer period when high grain temperatures prevail. In States south of latitude 40° N. the problem of keeping grain cool is more difficult and greater emphasis must be placed on keeping it dry.

### GRAIN SHOULD BE FREE FROM DOCKAGE

Wheat that is free from broken grains, grain dust, and other dockage is less liable than other wheat to damage from insect attack. Dry grain is not subject to attack by bran beetles if it is free from dockage, since the immature stages are usually unable to feed on the whole grains unless the moisture content or the temperature is high. If much grain dust is present, however, these stages can develop in grain that is rather dry, and the development of large numbers of them is likely to cause heating and spoilage.

### GRAIN SHOULD BE STORED IN CLEAN BINS

It is extremely important that wheat be stored in clean bins. Prior to filling with new grain, bins should be swept out and all old grain removed. If the bin is constructed of wood, the woodwork should be sprayed with an oil spray to kill all insects concealed in cracks and burrows. A technical white or other refined oil having a viscosity of S. A. E. 10 or less, free from objectionable odor, can be used, or a spray made from the following ingredients:

| | |
|---|---|
| Dormant tree spray oil | 1 gallon |
| Lye | 3 ounces |
| Water | 9 gallons |

A sufficient quantity should be used to cover the woodwork adequately without leaving an excess of the spray in the bin.

### DO NOT FILL THE BINS TOO FULL

Bins should not be filled higher than a point 6 inches below the top of the side walls, and the surface of the grain should be leveled. If the bins are filled any higher, or are heaped up, they will be difficult to inspect, to sample, or to fumigate, if fumigation is required. Fumigants cannot be applied uniformly to a heaped-up bin, and if the bin is filled to the top of the side walls the heavy vapors will roll over the side walls and escape.

## INSPECT FARM-STORED GRAIN FREQUENTLY

Grain should be inspected monthly if stored south of latitude 40° N., and at least early in the summer and late in the fall if stored in more northern areas. If two or more weevils or borers are present per 1,000 gm. (2.2 lbs.) of wheat, causing the grain to grade weevily, or if sufficient numbers of bran beetles are present to cause grain temperatures above the normal, the grain should be fumigated.

## FUMIGATE INFESTED GRAIN

For the treatment of infested farm-stored grain, fumigation is the most practical and economical procedure. Of the several fumigants available for this purpose the 3-to-1 mixture of ethylene dichloride and carbon tetrachloride is used extensively. This fumigant is effective, noninflammable, does not injure germination, and is not so hazardous or disagreeable to apply as are many other chemicals. Dosages required vary with the size and type of bin, 1,000 bushels of wheat in wooden bins or 1,000-bushel steel bins requiring 6 gallons, in 2,000-bushel steel bins 5 gallons, and in 2,740-bushel or larger steel bins 4 gallons.

Chloropicrin in combination with carbon tetrachloride, of a mixture consisting of 2 pounds of chloropicrin in enough carbon tetrachloride to make 1 gallon of the mixture, can be used in steel bins at the rate of 1½ gallons per 1,000 bushels of wheat.

In steel bins a mixture of 2 pounds of 1, 1-dichloro-1-nitroethane in enough carbon tetrachloride to make 1 gallon of the mixture can also be used at the rate of 1½ gallons per 1,000 bushels of wheat.

A mixture of 20 percent (by volume) of carbon disulfide with 80 percent of carbon tetrachloride is considered to be relatively free from fire hazard. Such a mixture can be used in steel bins at the rate of 2 gallons per 1,000 bushels of wheat. The use of "straight" carbon disulfide is not recommended on account of the fire hazard.

Recent tests indicate that carbon tetrachloride can be used in steel bins with satisfactory results at dosages as low as 3 gallons per 1,000 bushels of wheat. Its use in wooden bins is not recommended, owing to the difficulty of retaining the vapors long enough to effect a kill.

## PRECAUTIONS IN FUMIGATING

**In applying a fumigant to a bin of grain, the fumigator should avoid inhaling any of the vapors, even those from light concentrations, and avoid spilling the liquid fumigant on the clothing, hands, or other exposed surfaces of the body.** The fumigant should be applied from the outside of the bin. An inexpensive bucket sprayer or a larger power sprayer may be used to spray the liquid in a coarse stream uniformly over the surface of the grain. **It is unwise to attempt to fumigate a bin of grain by entering the bin and applying the fumigant with a sprinkling can. The vapors of grain fumigants have an anesthetic action when breathed in concen-**

**trated form, and fumigators exposed to the vapors for any appreciable period are likely to be made seriously ill.**

**A gas mask provided with a full facepiece, and a black canister approved by the United States Bureau of Mines for protection against organic vapors, should always be worn by anyone handling any of the liquid fumigants referred to in the preceding pages, or by anyone exposed to the concentrated vapors for more than a brief period. The canisters are not designed to protect against concentrations of these fumigants over 2 percent, nor should a caniser be used for more than 60 minutes of actual exposure to such concentrations. Canisters should be replaced frequently. Gas masks will not afford protection in heavy concentrations, such as would be encountered inside a bin being fumigated, or in situations where the air has been displaced by other vapors and oxygen is unavailable. When fumigants other than organic vapors are used, it is necessary to use a different canister, especially designed to protect against the particular fumigant used. For further information regarding gas masks, for cautions to be taken in the use of fumigants, and for first aid the reader is referred to pages 26 to 29.**

## Control of Infestations in Grain Elevators

The fundamentals of good storage of grain on the farm apply equally well to grain stored in elevators. The elevator operator has the advantage, however, of being able to handle the grain mechanically with speed and economy and to use grain-conditioning equipment that is not available to the average farmer

### CLEANING THE GRAIN

Cleaning the machinery can be relied on to remove many insects and damaged kernels from infested wheat. All screenings and grain cleanings that contain living insects should, of course, be disposed of in such manner as to prevent these insects from reinfesting the same or other grain. The most efficient machinery, however, will not remove all the free-living insects from the grain or the immature stages that live within the grain itself. Other methods, such as the application of cold, heat, or fumigants, must therefore be employed.

### COOLING THE GRAIN

It has been stated that insect damage can be prevented by keeping grain cool. In terminal elevators grain can be cooled during periods of cold weather by transferring it from one bin to another, dropping it through the chilled air, or running it over a series of baffles in the process. If the weather is cold enough, this method of treating grain is one of the cheapest and most effective that can be employed. The temperature of the grain cannot be lowered many degrees by a single turning or transfer unless the difference between the temperature of the grain and that of the air is considerable and the exposure to the cold air is prolonged by slowing down the movement. Oftentimes, however, even though the general temperature of the grain is not greatly lowered, turning the grain will break up colonies of insects and, by mixing the warm and cool portions of the grain, improve the temperature and condition of the grain as a whole.

## DRYING AND HEAT STERILIZATION OF GRAIN

A temperature of 140° F. for 10 minutes is fatal to all grain-infesting insects that are actually exposed to it. Sterilization of grain by heat can be used to advantage by the miller, because the loss of weight by evaporation of moisture from the wheat will not be objectionable and the heat does not injure the milling qualities of the grain. This method, however, is not considered entirely satisfactory for grain that is to be kept in storage.

In the killing of insects in grain by means of heat it must be recognized that the grain affords them a certain amount of protection. The air temperatures in the drier should therefore be higher than 140° F. or the period of exposure longer than 10 minutes. Grain driers of various kinds and types are on the market, but most of them are similar in principle, in that warm air is forced through layers of grain. Provision is also made for cooling the grain after sterilization by forcing cool air through it. According to Hurst and Black,[3] "An air temperature of 180° F. is considered the maximum allowable temperature for drying wheat without injury to the milling and baking qualities, and unless the temperature of the drying air can be accurately controlled it is advisable to operate at a slightly lower temperature. This is especially true if the grain is high in moisture content. Tests have shown that the germination of wheat, rye, oats, and buckwheat apparently was not impaired by artificially drying with heated air at 120°, 140°, or 160°."

## FUMIGATING THE GRAIN IN THE ELEVATOR

When other methods of treating grain in elevator storage to control insects are ineffective or for some reason cannot be employed, fumigation must be resorted to. A number of fumigants that are effective, relatively inexpensive, and simple to apply are available for use in elevators. They are calcium cyanide, chloropicrin, and mixtures of carbon disulfide or ethylene dichloride and carbon tetrachloride.

### CALCIUM CYANIDE

A granular crude calcium cyanide containing approximately 25 percent of available hydrocyanic acid, which is released slowly on exposure to atmospheric moisture, is an effective grain fumigant suitable for use in treating grain in elevator bins. In closed-top concrete or steel tanks a dosage of 10 pounds per 1,000 bushels is ordinarily used and gives a satisfactory kill under most conditions. In wooden-crib bins the customary dosage is 20 pounds per 1,000 bushels. In all cases double the prescribed dosage should be applied to the first and the last 500 bushels that enter the bin.

Specially designed, gravity-feed applicators are employed to introduce the calcium cyanide into the grain stream as the bin is filled. Specially calibrated feed plugs attached to the applicator regulate the flow of the calcium cyanide to correspond to the rate of flow of the grain. **Since hydrocyanic acid is deadly to human life, this fumigant must be handled with great care and by one trained in its use. While attending the applicator the operator should wear a gas mask equipped wih a white canister specially designed to protect against the vapors of hydrocyanic acid.**

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[3] HURST, W. M., and BLACK, R. H. GRAIN DRYING AT A COUNTRY ELEVATOR. U. S. Dept. Agr. Cir. 127, 15 pp. illus. 1930.

To fumigate a bin of grain, the cover of a 100-pound drum of calcium cyanide is removed, together with the rubber gasket and the instruction leaflet that will be found in the top of the drum. The large funnel of the applicator is then attached tightly over the opened drum by means of chains and hooks. The drum and funnel are then lifted and placed, funnel down, in the ring of the stand that has previously been assembled and set in place. By placing a piece of canvas around the bottom of the tripper spout the carrying of particles of calcium cyanide up into the head house along with the grain dust will be minimized.

As soon as the grain begins to flow into the bin the operator opens the feed-plug slide that allows the calcium cyanide to run into the grain stream. All the plugs are provided with two holes, so the double dosage required for the first and last 500 bushels can be obtained by allowing the calcium cyanide to flow through both holes for the necessary time. No other special attention is required except to replace drums as they are needed.

**The operator should keep away from the top of the bin while it is being filled, because the air displaced from the bin will carry some of the deadly gas. Bins should be fitted, if possible, with an outside vent to carry off the displaced air. In all cases it is essential to keep all bin-house windows open during the application of the fumigant.**

Treated grain should be allowed to stay in the bin at least 3 days before being moved. If grain is turned or loaded out in less than 2 weeks after fumigation, care should be taken to see that the tunnel room is well ventilated.

**Bins that have held grain fumigated with calcium cyanide should not be entered by workmen for several hours after the grain has been removed, unless forced ventilation can be employed, because dangerous concentrations of the gas may remain.** If the bins are over 40 feet high, and access is only from the top, the bottom slide should be left open and 25 to 50 bushels of wheat should be run through the bin, thus eliminating the necessity of sweeping it.

With calcium cyanide there is no fire or explosion hazard, so far as the fumigant is concerned. It has been found that fumigations conducted with the recommended dosage of 10 pounds per 1,000 bushels of wheat, or double this dosage, have no effect on the germination, milling, or baking qualities of treated wheat. It is not desirable, however, to subject to a baking test any flour milled from wheat fumigated less that 10 days previously, as traces of the gas would affect the action of the yeast.

### CHLOROPICRIN

Chloropicrin, one of the war gases, is also useful for the treatment of elevator grain. It is a colorless or slightly yellowish liquid a little more than 1⅔ times as heavy as water. It boils at 233.6° F. and on exposure to air it slowly forms a heavy vapor. At 77°, and with a pressure of 760 millimeters, the atmosphere saturated with chloropicrin vapor is 1.1458 times as heavy as air. The gas is nonexplosive and noninflamable as ordinarily used, is extremely toxic to insects and man, and, owing to its lachrymatory nature, has a very irritating effect on the eyes and the respiratory passages.

A dosage of 3 pounds of chloropicrin for oats and 2 pounds for other grains per 1,000 bushels, with an extra pound for the first and last 1,000 bushels, has been found to give highly satisfactory results. **While filling the applicator with chloropicrin and adjusting the flow of the fumigant, the operator must wear a gas mask fitted with a canister designed to afford protection from the fumes. For the comfort of the operators in the head house, the outside ventilators and the windows in the head house should be kept open during the application of the fumigant. Gas masks should also be available for any operator required to remain in the head house during the application of the fumigant. Upon completion of the treatment, the ventilators, the manhole, and other openings should be closed, and the grain should be left undisturbed for at least 48 hours, after which it can be turned.**

The fumigant is applied directly to the grain stream as the bins are being filled. A special applicator, consisting of a container with a valve and tube leading from the base into the tripper spout near the entrance to the bin, is used to apply the fumigant, the flow of which is regulated by the valve. If the rate at which the grain is flowing into the bin is known, it is a simple matter to make the proper adjustment of the valve.

The baking and milling qualities of the treated grain are temporarily seriously affected. If, however, the grain is well aerated, these deleterious effects pass off.

### ETHYLENE DICHLORIDE-CARBON TETRACHLORIDE MIXTURE

The ethylene dichloride-carbon tetrachloride mixture is an inexpensive noninflammable fumigant which has proved very effective for the treatment of grain stored in elevator bins. It is made up of 3 parts, by volume, of ethylene dichloride and 1 part, by volume, of carbon tetrachloride. The resulting mixture is a colorless liquid with an odor resembling that of chloroform. Regardless of the dosage, exposure, or moisture content of the grain, it has no adverse effect on germination. The vapor has an anesthetic action when breathed in concentrated form. **Although it is not so highly toxic as the fumigants previously mentioned, the operator should protect himself from the vapors with a gas mask equipped with a canister designed to protect against organic vapors.**

In the fumigation of elevator grain the mixture should be used at the rate of 3 gallons per 1,000 bushels of grain, applied to the grain stream as follows: 1 gallon poured on the first 100 bushels run into the bin, followed by 2½ gallons poured on the last few hundred bushels of each 1,000-bushel draft, or 4 gallons poured on the last few hundred bushels of each 1,500-bushels draft run into the bin, whichever is more convenient. The remaining portion of the dosage is sprinkled over the surface of the grain when the bin is filled. This dosage has been found effective at temperatures as low as 60° F. The fumigated grain should be left undistribed for at least 72 hours after treatment.

### CARBON DISULFIDE MIXTURES

Mixtures of carbon disulfide with carbon tetrachloride, to reduce the fire hazard, are now being used extensively for the fumigation of grain. Those mixtures consist of approximately 20 percent of carbon disulfide and 80 percent of carbon tetrachloride, by volume. Mixtures of carbon disulfide and carbon tetrachloride, as ordinarily used, have no deleterious effects on the germination of sound grain. **Operators should be reminded that the vapors of all such mixtures are toxic, and while using such mixtures should wear gas masks equipped with canisters designed to protect against organic vapors. The Division of Labor Standards, United States Department of Labor, warns that concentrations of 20 parts of carbon disulfide per million parts of air are dangerous.**

A dosage of 1½ gallons of the mixture per 1,000 bushels of grain gives a good commercial kill. For best results, it should be applied in proportionate doses to every 1,500-bushel draft of grain as the bin is being filled, in somewhat the manner described for the ethylene dichloride-carbon tetrachloride mixture. An application schedule for a 6,000-bushel bin with a dosage of 1½ gallons per 1,000 bushels is as follows: 2 gallons applied with a sprinkling can to the grain stream toward the end of the first, second, and third 1,500-bushel drafts, respectively, and the remaining 3 gallons toward the end of the last 1,500-bushel draft. An exposure period of at least 72 hours should be allowed.

### CARBON TETRACHLORIDE

Carbon tetrachloride alone is an effective fumigant for elevator wheat. It is noninflammable and does not impair the germination. It should be applied in the manner recommended for the mixture of ethylene dichloride and carbon tetrachloride and at the same dosage of 3 gallons per 1,000 bushels. The vapors of this chemical do not kill so rapidly as some fumigants, so a longer exposure period is required for the most efficient results. For this reason grain fumigated with carbon tetrachloride should be allowed to remain in the bin 2 weeks without being turned.

## Treatment of Grain in Warehouse Storage

In some parts of the country, warehouse storage of bagged grain is practiced. Such storage may be used alone or in conjunction with elevator storage. When it is desired to fumigate warehoused, bagged grain, it may be treated without handling by fumigating the entire room or building, provided the building is of modern concrete or brick construction. If the building is of any other type of construction, individual lots of grain can be fumigated under tarpaulins.

For the fumigation of a modern tight warehouse of concrete or brick construction, filled with bagged grain, the use of methyl bromide is recommended. Methyl bromide has remarkable powers of penetration through large stacks of bagged grain and has no deleterious effects on the germination or quality of the grain, unless excessive dosages are used or the vapors are retained through lack of aeration. It cannot be used successfully in loosely constructed buildings. Directions for the fumigation of bagged grain in warehouses or under tarpaulins with methyl bromide will be found on pages 63–64 and 71–72.

### Effect of Fumigants on Germination

The germination of wheat may be affected by some fumigants if the moisture content of the grain is over 12 percent, the dosage excessive, or the exposure period prolonged.

In the fumigation of farm-stored wheat that cannot ordinarily be turned after fumigation, it has been observed that fumigants may be retained for several weeks or even months in tight steel bins. The ethylene dichloride-carbon tetrachloride mixture does not appear to affect germination of wheat, regardless of the dosage, length of exposure, or moisture content of the grain. Hydrocyanic acid at commercially used dosages does not impair the germination of wheat suitable for storage. Carbon disulfide is likely to impair germination if the moisture content is above 12 percent. Chloropicrin and methyl bromide are likely to impair germination if wheat has a moisture content of over 12 percent or if it is fumigated in tight bins and left without being turned. In tight bins the vapors are likely to be retained by the grain for long periods, therefore the exposure period is excessive.

## INSECTS FOUND IN FLOUR MILLS

As previously stated, the insects that cause the greatest damage to grain in storage are not of vital importance in the flour mill, because they are unable to damage milled cereal products seriously. Some of the minor pests of stored grain are the ones that are really troublesome in flour mills.

### Flour Beetles

The confused flour beetle (fig. 5) and the red flour beetle (fig. 6) are the insects most abundant in flour mills. They are reddish-brown beetles about one-eighth of an inch in length, and the two species are almost identical in appearance. Coming in with the grain, some of them pass uninjured through the break roll, drop through the first top screen on the first break sifter, and are carried on to the purifiers, where they establish colonies in the conveyers. They eventually spread to all parts of the milling machinery and are the insects most commonly found in flour after it leaves the mill. They are also brought back to the mill with returned infested products, in clears and low-grade flours purchased for blending operations, and in used bags.

A third species known as the black flour beetle (*Tribolium madens* (Charp.)) is sometimes found in mills in the north-central part of the country. It is similar in appearance to the other flour beetles except that it is black.

The adults of the flour beetles are long-lived, some of them surviving for nearly 2 years. The females lay, on an average, 400 to 500 eggs each, dropping them here and there in the flour or foodstuff. The developmental period from egg to adult varies greatly, and is depend-

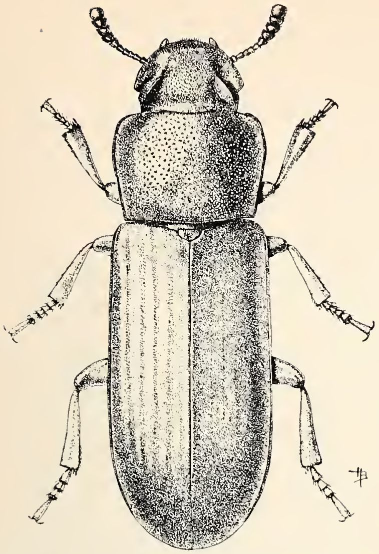

FIGURE 5.—The confused flour beetle, undoubtedly more troublesome in flour mills than any other insect except the closely related red flour beetle.

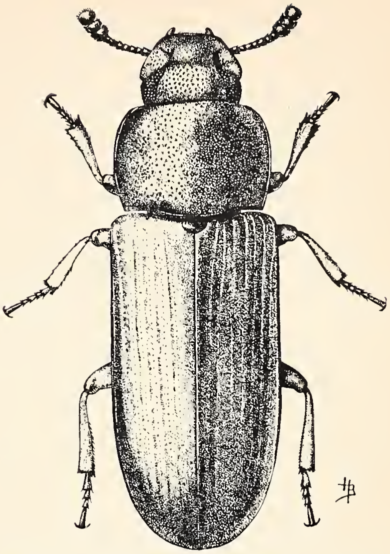

FIGURE 6.—The red flour beetle, in common with the confused flour beetle, one of the most troublesome insects found in flour mills.

ent on the food supply, the temperature, and the humidity. With high temperature and humidity and with ground whole kernels of wheat as food, the life cycle may be completed within 4 weeks. With patent flour as food, however, it is doubtful whether, even with the most favorable conditions of temperature and humidity, the average developmental period would be less than 6 weeks, and it would frequently be much longer. Flour beetles breed most rapidly at a temperature of about 90° F., but they are also capable of breeding in flour at a temperature of 70°. No development has been ordered at 65° or below.

## The Mediterranean Flour Moth

The Mediterranean flour moth (*Ephestia kuehniella* Zell.) (fig. 7) was formerly the most troublesome insect pest of flour mills, owing to

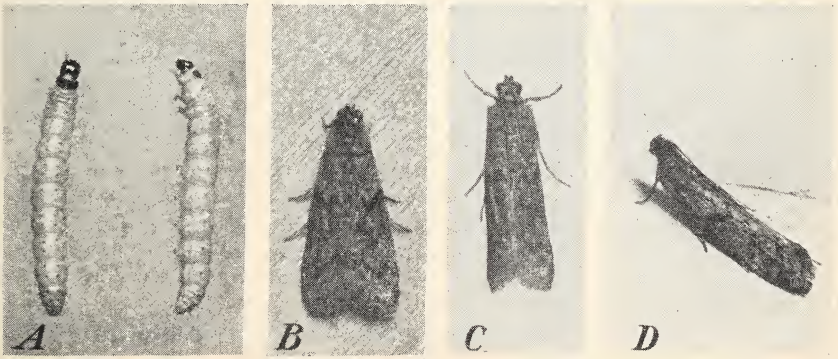

FIGURE 7.—The Mediterranean flour moth: *A* Larvae; *B*, *C*, and *D*, adult in various positions.

its abundance and the habit of the larvae, or worms, of spinning silken threads wherever they crawl, webbing and matting the flour particles together (fig. 8) until milling machinery becomes so clogged that the operation of the mill is seriously impeded and shut-downs are frequent. Although this insect is no longer a serious pest in mills that practice an annual fumigation, it is still common in mills along the West coast and is a major problem in all parts of the country in small mills that do not make a practice of fumigating regularly.

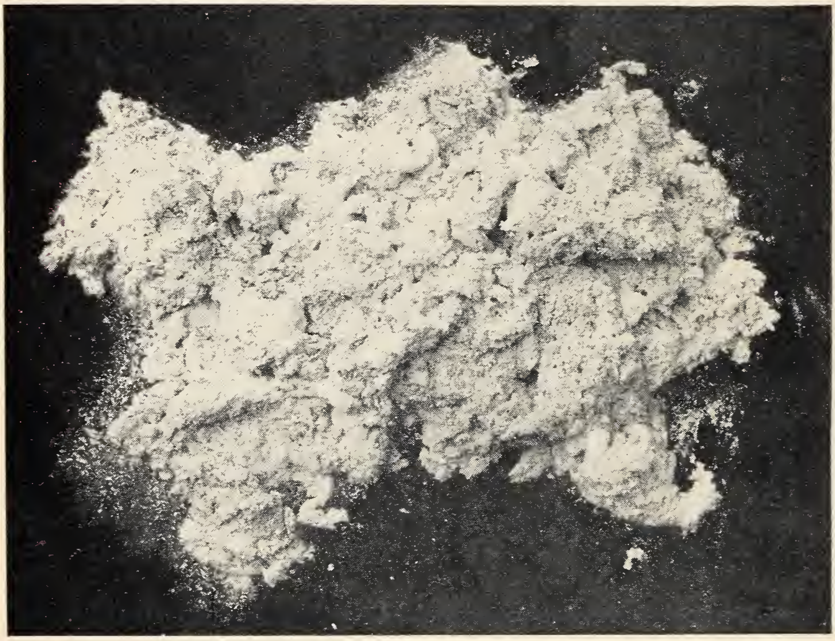

FIGURE 8.—Mass of flour particles matted together with silken threads spun by the caterpillar of the Mediterranean flour moth. When the flour moth is abundant, machinery becomes clogged with the matted flour.

The adult moth has a wingspread of about 1 inch; its hind wings are a dirty white, and the fore wings are a pale gray, transversed with wavy black lines. The female moths lay their eggs in accumulations of flour or other milled cereal products. In a few days these eggs hatch into the caterpillars, or worms, that when fully grown are about half an inch long. They are whitish or pinkish, with a few small black spots on the body. Under favorable conditions of temperature and humidity, the developmental period from the egg to the adult is about 8 or 9 weeks.

## THE INDIAN-MEAL MOTH

The Indian-meal moth (*Plodia interpunctella* (Hbn.)) (fig. 9) is seldom a pest of milling machinery, although it is frequently seen in flour mills. It prefers the coarser grades of flour and milled cereals and is the insect most commonly found in packages of whole-wheat flour, graham flour, and corn meal. Its larvae, like those of the Mediterranean flour moth, spin silken threads, and infested products are usually matted together by the silken webs. Infestations of this moth are occasionally found in the middlings purifiers.

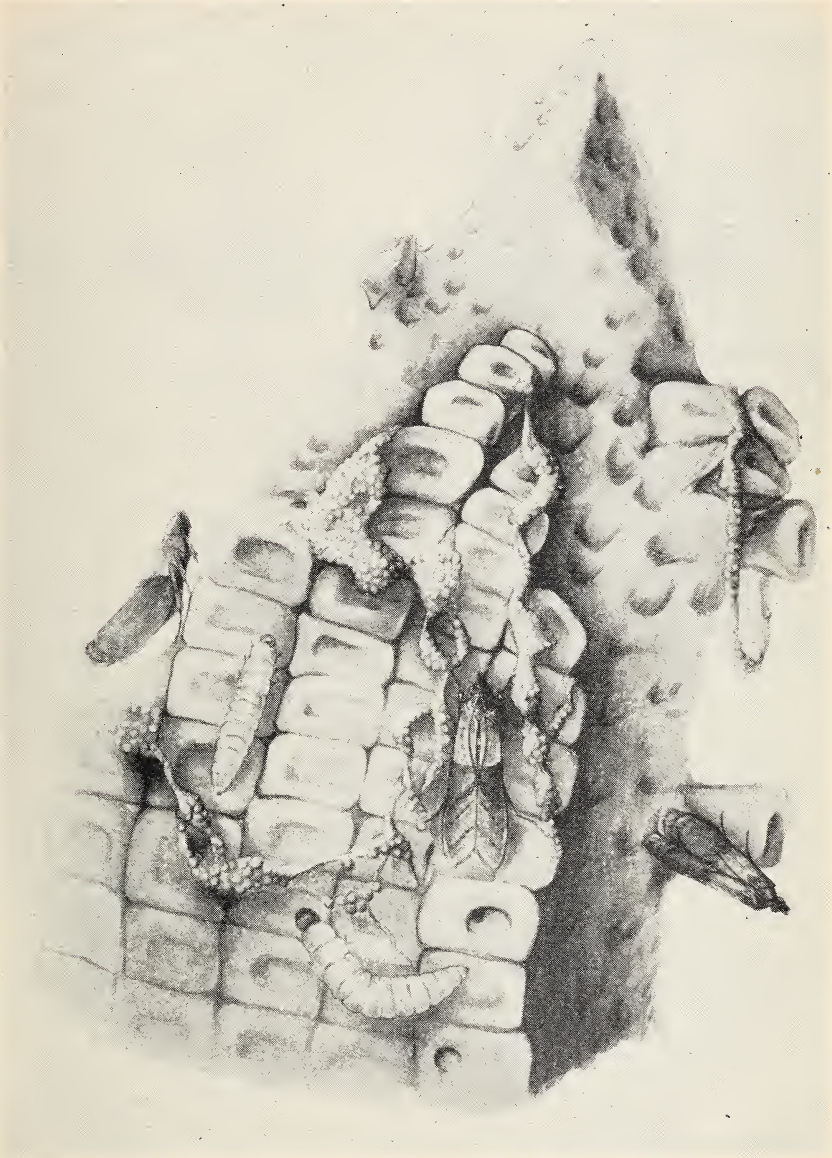

FIGURE 9.—The Indian-meal moth, sometimes troublesome in flour mills.

The adult moth has a wing expanse of about three-fourths of an inch. It is handsomely marked and can be distinguished from other flour- or grain-infesting moths by the characteristic markings of its fore wings. These are reddish brown with a coppery luster on the outer two-thirds, but whitish gray on the inner, or body, end. The female moths lay an average of 200 eggs, placing them singly or in clusters on the foodstuff. The caterpillars that hatch from the eggs are dirty white, with sometimes a tinge of green or pink. When fully grown they are about half an inch long. Under favorable conditions of temperature and moisture the period from egg to adult occupies about 4 weeks.

## THE CADELLE

The cadelle (*Tenebroides mauritanicus* (L.)) (figs. 10 and 11), sometimes called the "lobster bug," is known to many millers as the "bolting-cloth beetle" because of its habit of occasionally cutting the silk cloth in bolting reels and redressing machines. The beetles do not feed on the silk, but on grain, flour, and other milled cereal products. Both larvae and beetles are commonly found in accumulations of stock in the bottom of elevator boots and flour conveyers, particularly in old wooden mills where the elevator boots are on the floor and where the woodwork has become infested. The wooden slides of elevator boots are sometimes literally honeycombed with the burrows of the worms. The cadelle also becomes established in the woodwork of storage warehouses, railway box cars, and steamships, invading bagged cereal products during storage or in transit.

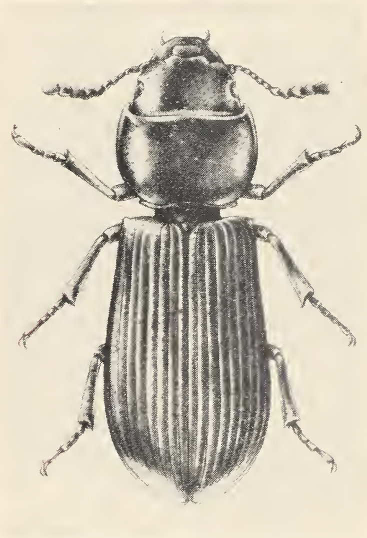

FIGURE 10.—The cadelle, commonly found infesting both grain and flour.

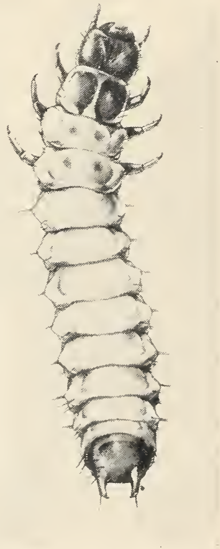

FIGURE 11.—Larva of the cadelle. Such larvae are often screened out of old flour in large numbers.

The adult cadelle is an elongate, oblong, flattened, black beetle about one-third of an inch long. The adults live for from 1 to 2 years, and the female beetles lay about 1,000 eggs each. The larvae are about three-fourths of an inch long when fully grown, fleshy, and have abdomens terminating in two dark, horny points. They are white, with the head, the thoracic shield, and the two horny points at the end of the body, black.

Under favorable conditions of temperature and humidity and a plentiful supply of food, the period from egg to adult occupies about 10 weeks, although it is usually much longer under normal conditions.

## The Black Carpet Beetle

The black carpet beetle (*Attagenus piceus* (Oliv.)) (fig. 12) belongs to a group of beetles that are scavengers. The larva, which is the only stage that is injurious, is nearly omnivorous, feeding on fabrics, milled products, and all types of dried animal matter. It is commonly found in accumulations of waste-grain products and in cracks in wooden floors, where flour and lint collect. When bolting reels and redressing machines are allowed to stand idle, considerable damage is sometimes caused to the silk cloths by the feeding of the larvae (fig. 13).

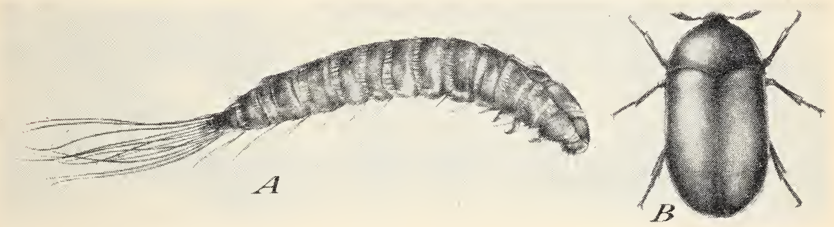

Figure 12.—The black carpet beetle, which occasionally causes serious damage to the silks of machines not in use. *A*, Larval skin, showing the typical shape of the larva and the long tuft of bristles at the end of the body ; *B*, adult beetle.

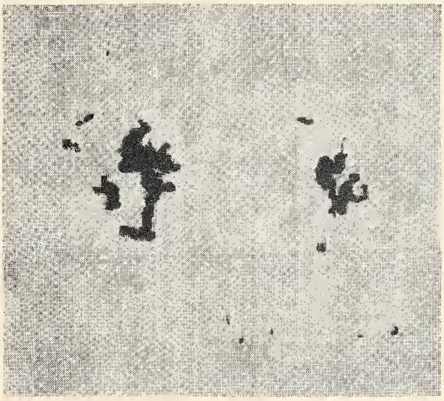

Figure 13.—Damage to silk bolting cloth caused by larvae of the black carpet beetle.

The adult is a small black beetle between two- and three-sixteenths of an inch long. It is frequently seen in mills in the spring, crawling on the windows, over the bags of flour and feed, and on the floors. The beetles lay their eggs in any convenient supply of foodstuffs, and these soon hatch into reddish-brown or golden-brown worms, clothed with short hairs and bearing a tuft of long hairs at the end of the body.

There is only one generation a year. The larva develops slowly throughout the year and transforms to an adult beetle in the spring.

## THE SAW-TOOTHED GRAIN BEETLE

The slender, flat, brown saw-toothed grain beetle (fig. 14) gains its name from the peculiar structure of its thorax, which bears six saw-toothed projections on each side. It is about one-tenth of an inch long. It is a cosmopolitan pest of stored grain and grain products of all kinds. Although often found in flour mills, it is usually more troublesome in warehouses.

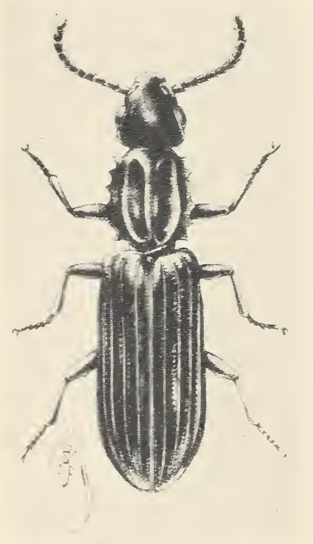

FIGURE 14.—The saw-toothed grain beetle, found in grain and in flour products that have been in the warehouse for some time.

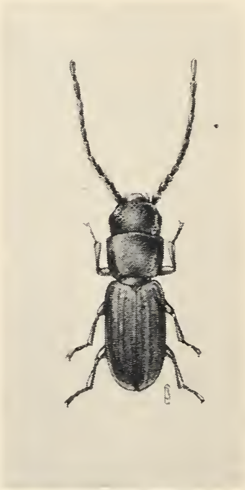

FIGURE 15.—The flat grain beetle, the smallest beetle found in stored grain. It is often abundant in milling machinery. Damage caused by its feeding is slight.

The adult beetles may live for more than 3 years, although the average length of life is from 6 to 10 months. The females lay from 45 to 285 eggs each. In summer the developmental period may be passed in as few as 22 days.

## THE FLAT GRAIN BEETLE

The flat grain beetle (fig. 15), a small flattened, reddish-brown beetle, is the smallest beetle commonly found in the flour mill, being only about one-sixteenth of an inch long. It does little active damage by its feeding, but its presence is undesirable. After a fumigation the dead bodies of this species are often seen in numbers on the floor near elevator boots or in the sifters. The flat grain beetle feeds in grain and grain products of all kinds, but the details of its life history are not well known.

### COCKROACHES

Cockroaches are very common in the basements of many flour mills. After a fumigation they can sometimes be swept up by the bucketful. The oriental cockroach (*Blatta orientalis* L.) (fig. 16) and the American cockroach (*Periplaneta americana* (L.)) (fig. 16) are the species most commonly found.

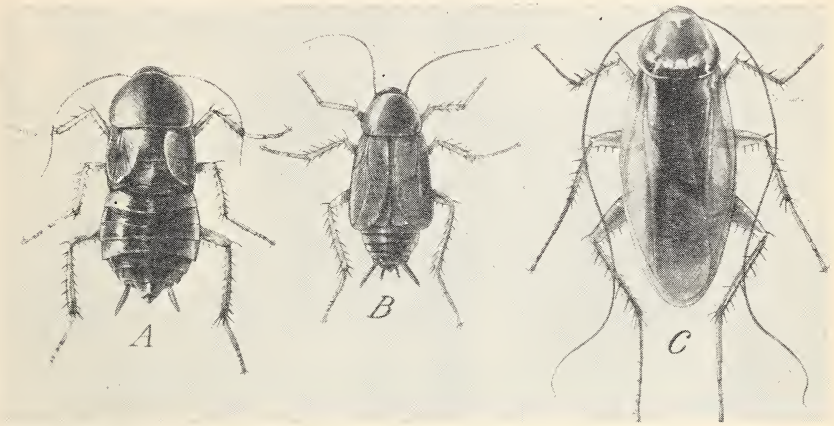

FIGURE 16.—Cockroaches that are common inhabitants of the basements of flour mills: *A*, Female, and *B*, male, of the oriental cockroach; *C*, the American cockroach.

## AVENUES OF INFESTATION IN FLOUR MILLS

The insect population of a flour mill is of vital concern to the miller, and the ability of a mill to put out an insect-free product is closely related to the insect population in its milling streams. A thorough understanding of how insects get into the mill and of the conditions that either check or promote their multiplication is therefore essential.

Flour mills may become infested with insects in many ways. Years of observation have demonstrated that the more important of these are: (1) Insects entering with the grain stream; (2) insects from infested clean or low-grade flour used in blending operations; (3) insects from infested flours returned to the mill from grocers, warehouses, or other sources; (4) insects in returned second-hand bags; (5) insects in second-hand machinery purchased by milling organizations for installation in their plants; (6) insects from infested feeds stored in the mill near the milling machinery; and (7) insects from nearby elevators.

Information relative to insect populations in milling machinery at different times of the year, and as affected by different methods of milling practice and insect sanitation, has been obtained through monthly collections of samples of stock from a number of mills over a period of several years. It has been found that in general the insect population is relatively small in winter, rises rapidly in spring, is reduced in most mills to a low ebb in July by fumigations, and rises rapidly again until fall, when it begins to decline with the onset of cold weather.

Of 2,367 8-ounce samples of stock taken from elevator boots or purifier conveyors during 1934–35, 80 percent were found to be infested. In these samples 74,175 insects, representing 30 different species, were found. The relative abundance of the 6 species occurring most frequently is shown in figure 17. As may be seen, the flour beetles (*Tribolium* spp.) were predominant.

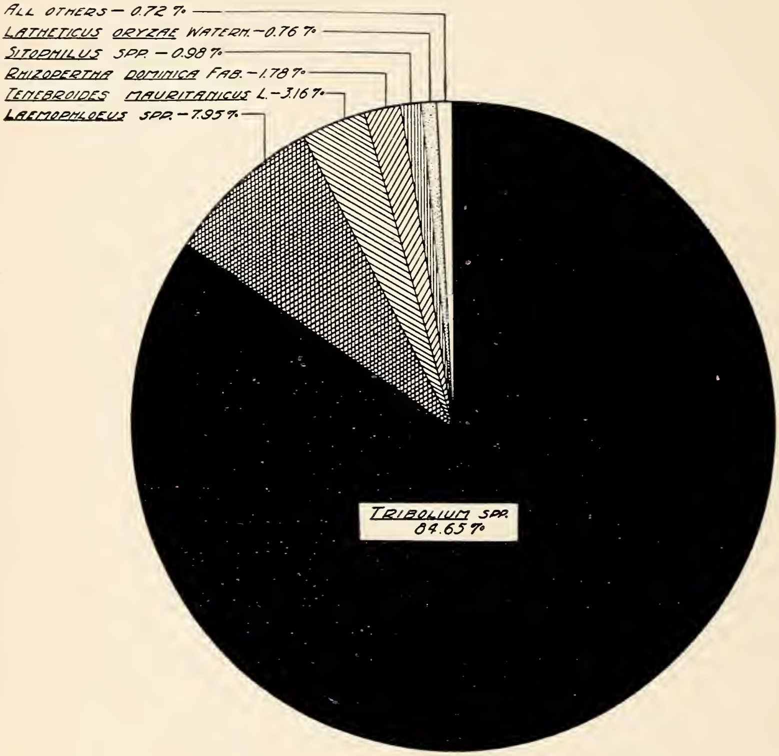

FIGURE 17.—Percentages of different species of insects taken in milling streams of 17 flour mills in Kansas, Oklahoma, and Missouri, during 1934–35. (Total, 74,175 insects.)

## THE GRAIN STREAM

Of the many sources of insect infestation in the flour mill, the grain stream is usually the most important. Grain coming to the mill is often infested, although the degree of infestation varies with the location of the mill and the source of the grain. It is noticeable that mills in the spring-wheat region and in the Pacific Northwest, which handle only locally grown wheats, have fewer insect troubles than mills in the Southwest, where as many as 30 different species of grain-infesting insects have been found in grain arriving at the mills. The fact that many mills find it necessary to draw wheat from many sources to meet their requirements often complicates their insect problem considerably.

Grain-cleaning machinery now in use does not adequately remove insects from the incoming grain. This is clearly shown by the data in figure 18, which indicate the average numbers of insects and proportions of different species found in 8-ounce samples of milling stock from the different milling streams of 17 flour mills in the Southwest, taken at monthly intervals during 1934–35. It may be noted that samples from the wheat elevator boot, which handled the wheat after cleaning, had a high average insect population. Previous investigations have shown that it is possible for insects to pass uninjured through the entire system of rolls. Adults of the confused flour beetle have been observed to pass unharmed through the first 3 breaks, and partly grown larvae are able to survive passage through the first 3 middlings rolls. Eggs of this species are so small that many of them survive passage through the low-grade flour rolls. These eggs hatch and start infestations, which may quickly reach serious proportions in all streams of the milling unit.

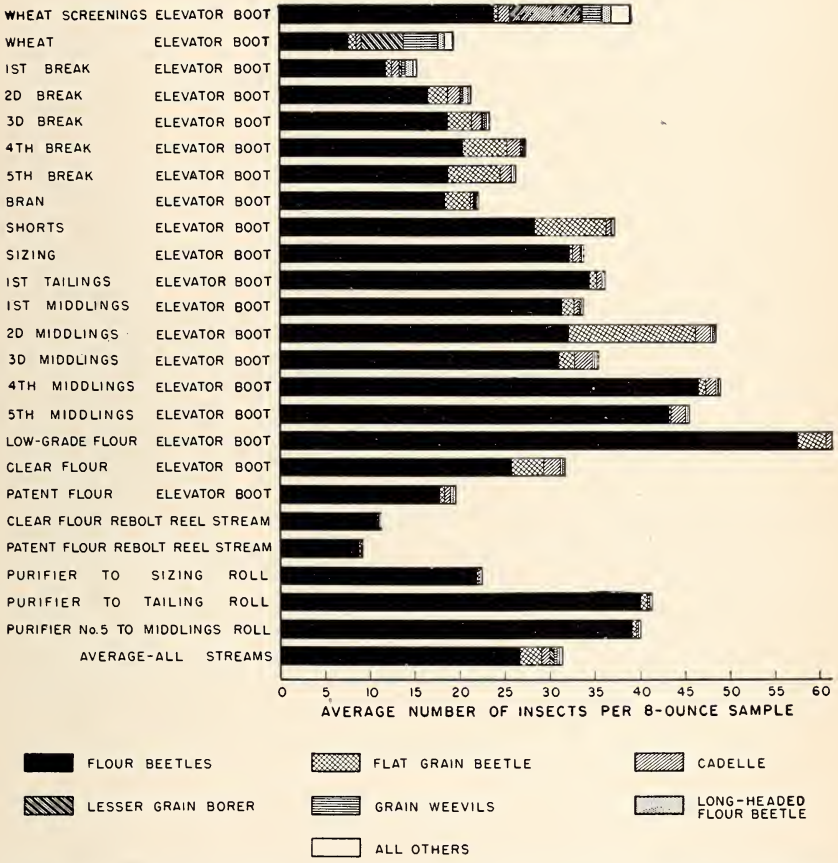

FIGURE 18.—Average numbers of insects per 8-ounce sample and proportions of different species found in 2,367 samples from the different milling streams of 17 flour mills in Kansas, Oklahoma, and Missouri in 1934–35.

As also shown in figure 18, screenings from wheat that has come from the elevator are usually heavily infested. In many mills the cleaning machinery is placed close to the milling units, and in some instances screenings are spouted to a collecting sack located near milling machinery or stored finished flour. In such cases any insects that may crawl from these screenings have easy access to the milling machinery or finished flour.

Grain-cleaning machinery should be segregated in a smut room at one end of the mill, and grain screenings should be disposed of immediately by spouting to a screenings hammer-mill, a centrifugal-force machine, or to a vault where they can be fumigated or sterilized by heat. Grain screenings should never be allowed to accumulate in the mill or in the flour warehouse.

The use of centrifugal force to destroy infestation in wheat mechanically can be employed to treat the grain stream just before it reaches the first break rolls. The device used to treat the wheat is used mainly for the treatment of flour and other milled cereals and is described later in this circular under the heading "Treating Flour with Centrifugal Force." Free-living insects in the grain are killed by impact during passage through the machine. Tests have shown that when operated at a speed of 1,750 r. p. m. more than 99 percent of the free-living insects in the grain are killed, whereas breakage of tempered wheat is unappreciable.

## Stocks Used For Blending Purposes

The demand for blended flour by large baking concerns necessitates the use by mills of large quantities of clear and low-grade flours which may be obtained in part from other mills and in part from their own warehouses. Usually these flours have accumulated over a period of time and, being highly susceptible to insect attack, are frequently infested.

The use of such stocks for blending during milling operations is oftentimes one of the most serious causes of infestation in the mill. If these stocks are infested and are not properly treated before they are blended in, the milling machinery handling them and the resulting flours become infested.

It is customary for such stocks to be redressed prior to blending; however, reels used for this purpose are seldom equipped with bolting cloth fine enough to prevent the passage of eggs and small larvae, and cannot be relied on to remove all insect life. The introduction of such flour into mixing conveyers leading to packer bins is a common cause of infestation in finished flour.

Flour intended for blending should be run through a reel and then through a treating machine using centrifugal force, which will destroy all insect life, or it should be bolted over a redress sifter clothed with 10XX bolting cloth. If the latter method is used the overs should be spouted directly to feed.

Stock intended for blending should first be examined to determine whether it contains insect excrement or is heavily infested. Insect excrement in flour cannot be removed by any practical rebolting process and flour that contains or has contained an appreciable infestation of insects is considered unfit for human consumption and should be diverted to feeds. Methods for detecting excrement in flour are described on pages 62–63.

## Returned Flours

Returned flours are always a problem to the miller, since they invariably constitute a serious source of infestation. Formerly it was the custom to feed these flours back into the mill and to incorporate them into one of the many blends required by modern market demands. If, as was usually the case, these flours were infested, the same difficulties were experienced as described in the preceding paragraph when infested clears are used for blending.

Returned flour that is seen to be infested should be fumigated, sterilized by heat, or treated by centrifugal force, and diverted to feed immediately on receipt. It should never receive temporary storage in the mill or flour warehouse.

Mills that deliver by truck encounter the problem of providing for the return of infested flours during their regular delivery trips. These infested flours are a source of infestation for the freshly milled flours in the truck alongside of which they are stacked. Not infrequently, insects crawling from the infested products are delivered to customers along with fresh stocks of flour. If it is necessary to pick up returned flour products in the course of a delivery trip, the truck should be provided with a separate compartment into which these products can be placed and which has no connection with the part of the truck carrying freshly milled products, the trucks should be thoroughly cleaned between trips, and the sweepings should be burned or otherwise treated so as to destroy the insects they contain.

## Used Bags

It is the custom of many baking concerns to salvage the bags in which flour is shipped and return them to the mills for refilling. The saving thus effected is thought by the baker to be well worth while, particularly when bag materials are scarce. Some firms have the used bags washed before returning them to the mills, but unfortunately this is not the universal custom. In many cases the emptied bags are accumulated in piles awaiting shipment back to the mill. The flour particles adhering to the bags attract insects, which breed in numbers in such situations. The infested bags sent back to the mills may contaminate the railways cars in which they are shipped, and on arrival at the mill are all too likely to be thrown into the bag room, or a corner of the mill or warehouse, where they serve as a constant source of infestation for the mill. Prior to refilling they are usually run through a bag cleaner or are cleaned by some type of air suction. These methods seldom remove all stages of flour-infesting insects, and fresh flour packed in them is likely to become heavily infested if held in storage for any appreciable time. The infested material removed from the bags by the cleaning process constitutes another problem in the mill for, unless properly disposed of, it provides an additional sources from which infestation can spread.

If the use of second-hand bags must continue, methods should be employed to destroy the insects they harbor. The most satisfactory method is to have the bags carefully laundered. Failing this they should be received at the mill in a room or building separate from the mill or storage warehouse, where they can be fumigated or sterilized by heat. If heat sterilization is employed, the bags should not be subjected to temperatures above 180° F. for over 24 hours, because prolonged exposure to high temperature weakens the bag material.

Paper bags of every description are now being offered to the trade as a substitute for the more expensive fabric bags, and there is little doubt that they will eventually replace a large portion of them.

### Second-hand Machinery

Used machinery occasionally is purchased from mills that are being dismantled. All milling units are likely to contain some infestation, and machinery that has been lying idle for some time is almost sure to be heavily populated with insects, because they thrive and reproduce rapidly in undisturbed accumulations of milling stock. Unless proper precautions are taken, used machinery brought into the mill may introduce insects previously not established there. Infestations of the Mediterranean flour moth are known to have been frequently carried from one mill to another in this way.

If possible, second-hand milling machinery should be fumigated in an atmospheric vault before it is set up in its new quarters. If it is too large to be placed in any atmospheric vault that is available, it can be fumigated under a tarpaulin or in a railway box car.

### Feeds Stored in the Mill or Flour Warehouse

The practice of storing certain feeds in the mill or flour warehouse during periods when such feeds accumulate is exceedingly common. It is difficult to produce feed that is entirely free from insect infestation, owing to the impossibility of sifting it through fine enough mesh to remove insect life, therefore feeds stored near flour or milling machinery constitute a potential source of insects sure to migrate from these products.

Feeds can be treated by centrifugal force in such a manner that all insect life is killed, but until mills are equipped to handle their feeds in this way care should be taken to see that they are stored in a separate warehouse as far as possible from the mill and the flour warehouse.

### Infestation From Nearby Elevators

Many of the insect pests of stored grain and milled cereal products are strong fliers. During grain-cleaning operations it is not uncommon for insects removed in the process to be blown out into the open air. Many of these insects will fly from nearby elevators to the flour mill, where they will start infestations in elevator boots or in any milling unit into which they can crawl. The red flour beetle and the flat grain beetle are two species most likely to come from such sources. Insects removed in grain-cleaning operations should be destroyed immediately.

## PRACTICAL MEASURES FOR CONTROLLING INFESTATION IN THE MILL

In the preceding pages the principal sources of insect infestation in the flour mill have been enumerated and methods proposed for preventing infestation from these sources. Owing to the lack of adequate machinery, insufficient help, or circumstances beyond the control of the management, insect infestation is likely to creep into the mill and complicate the problem of producing insect-free flour. There are several ways in which the insect population of a flour mill can be eradicated, held at a minimum, or prevented from contaminating the finished product.

A general fumigation, if properly conducted, will eliminate most of the insect population in a flour mill; but if, as is often the case, the grain stream entering the mill is infested, the milling machinery may become reinfested with insects within a few weeks. Insects appear in the purifier conveyors and elevator boots, and in warm weather may soon be as abundant as ever. A few surviving insects in accumulations in various milling units, dead spouts, dust-collecting machinery, and under wooden floors provide for a steady increase of infestation. In a mill of modern construction, however, the weekly cleaning out of stock from elevator boots and a local fumigation of purifier, reel, and flour conveyers every 3 or 4 weeks will hold insect infestation to a minimum between general fumigations. This program of insect control should be adopted by all mills.

## Keeping the Tail End of the Mill Free From Insects

The tail end of the mill is that portion of the milling machinery between the main bolters and the packer bins. By keeping this part of the mill free of insects, the presence of a few insects in other parts of the mill will not necessarily prevent the production of insect-free flour. The main bolters act as a natural barrier against insect infestation entering the tail end of the mill, since the sifter screens through which all flour must pass before it enters the flour-collecting conveyers are clothed with silk bolting cloth fine enough to remove all insect life. Breaks in the silk bolting cloth, however, occasionally occur, allowing insect infestation to pass through into the flour-collecting conveyers. Furthermore, whenever sifter sections are opened for inspection or repair, infested tail-overs may drop into the flour spouts and into the conveyers unless the sifter socks are first removed. In making inspections and repairs to sifters, the lower sifter socks should be first removed and a close-fitting metal cap should be placed over the sock connecting with the slide spout until repairs have been completed and sifter sections have been thoroughly cleaned. If this is practiced at triweekly intervals, infestations that develop because of breaks in the cloth will be taken care of by local fumigation before they can build up to serious proportions.

If infestations are allowed to build up without restraint in milling units in front of the main bolters, the danger of insects getting past the bolters by the avenues mentioned will be increased. When insects are abundant in any part of the mill, they will migrate; and if flour conveyers are of wooden construction or not entirely tight, insect infestation will result from the entry of these migrating insects or their progeny.

The introduction into mixing conveyers of clear, low-grade, and returned flours from rebolt reels is also an important source of infestation in the tail end of the mill. Such stock should be freed from insect life before it is used for blending purposes.

### INFESTATION IN THE FLOUR-COLLECTING CONVEYERS

The flour-collecting conveyors in the average mill are likely to be neglected, owing to their inaccessibility. They are rarely cleaned out, and in the worm-type conveyer there is always a certain quantity of flour in the bottom that is rarely disturbed and in which insects may breed without interruption. The ideal method of keeping these conveyers clean is to install a drag-type conveyer that will carry all the flour through it and prevent infestations from becoming established. The installation of removable bottoms will also provide a method of completely cleaning out conveyers at regular intervals or whenever infestations are suspected. Periodic local fumigation is the next best method of keeping these conveyers free of insect life. Directions for doing this operation are given on page 51.

### PREVENTIVE MEASURES

The removal or prevention of accumulations of milling stock in any part of the flour mill should be made one of the most important phases of the insect-control program. Insects will breed in any accumulations of flour stocks that are permitted to remain undisturbed. It should be the duty of some member of the milling personnel to study the mill and determine how best to eliminate danger spots.

Unused conveyers, slide spouts, or any piece of unused equipment in which flour collects, should be eliminated. Many pieces of milling equipment rest on the floor in such a way that flour dust collects between them and the floor, providing ideal insect-breeding places practically impossible to clean. Whenever possible such equipment should be raised far enough above the floor to allow easy and frequent cleaning. Elevator boots, in particular, should be raised above the floor, because they not only harbor insects underneath them but because insects crawling about on the floor can readily enter them and crawl from a heavily infested elevator boot to one carrying clean stock. By rounding the bottoms of elevator boots, the quantity of milling stock that can accumulate in them can be reduced in some cases as much as 80 percent. The periodic removal of accumulations of mill stock from elevator boots is highly desirable in order to keep down mill-insect populations. This stock should be fumigated, sterilized by means of heat, or treated by centrifugal force.

## FUMIGATION IN THE FLOUR MILL

### GENERAL PROCEDURE AND PRECAUTIONS

At times all mills become so heavily infested that simple sanitary measures are insufficient and more effective treatments, such as fumigation or heating, are necessary.

**The fumigation of flour mills and warehouses is a specialized operation, the success of which is dependent on the care and skill with which it is accomplished. Owing to this fact and also because the fumigants used in the work are highly toxic and dangerous to handle, it is usually best to have general mill fumigation done by professional fumigators who make a practice of the art and guarantee their work.** Reliable fumigating concerns are usually available in all parts of the country on reasonably short notice and render good service for a moderate price. Some of them specialize in mill fumigation and are particularly well equipped for it. In some cases and for certain types of fumigation large concerns may wish to keep a corps of workers specially trained to carry on fumigation work.

**All fumigants used to combat insects in flour mills and warehouses are highly toxic to human beings. It is therefore necessary to take every precaution to avoid exposure of the operators to heavy concentrations of fumigants. If in the application of fumigants the operators must expose themselves to the vapors, or if it is necessary to enter a building being fumigated in order to open it up for ventilation or any other purpose, they must wear gas masks.**

## The Construction of Gas Masks

Gas masks consist essentially of a facepiece and a canister. The most popular and commonly used type in this country has a breathing tube connecting the facepiece with the canister. In some cases, a skeleton-type mask is used, the facepiece being eliminated. In this type the nostrils are closed by a clamp and the wearer breathes through a rubber device inserted and held in the mouth. This type does not protect the eyes from irritating gases and is not recommended. The type popular in this country consists of a facepiece of rubber or rubberized fabric which can be adjusted to fit tightly across the forehead, along the cheeks, and under the chin, and is connected by a short, flexible, noncollapsible tube to a sheet-metal canister containing absorbent materials. A light harness or knapsack is provided to suspend the canister from the shoulders or to strap it to the chest. The facepiece is provided with shatter-proof glass eyepieces and with a check valve through which exhaled air escapes. At the bottom of the canister is a check valve, which opens only to admit air.

For each of the gases likely to be encountered in fumigation work, a special canister is available. Most canisters are charged with materials intended to absorb only a limited number of closely related gases, although the all-service canister is designed to afford protection from a combination of gases. A color code has been adopted by the Bureau of Mines whereby canisters designed for different gases are assigned a specific color, e. g., a white canister is designed to give protection against low concentrations of acid gases such as hydrocyanic acid and sulfur dioxide; a black canister, against organic vapors such as carbon disulfide, carbon tetrachloride, chloropicrin, ethylene dichloride, methyl bromide, and ethylene oxide; a yellow canister, against a combination of acid gases and organic vapors; and a red canister against a combination of gases. (A list of gas masks of different makes that have been approved by the U. S. Bureau of Mines is given in Bureau of Mines Information Circular 7030.)

### LIMITATIONS OF THE GAS MASK

Before using a gas mask in fumigation work the operator should realize that it has certain limitations. **(1) A mask of the type described above cannot be safely used in an atmosphere that is se-**

**riously deficient in oxygen.** A gas mask ceases to be adequate if, in the presence of an excess of a simple asphyxiant gas, the oxygen content of the air falls below 14 percent, even though it removes any toxic gas present in the respired atmosphere. It is unable to supply the oxygen necessary to support life. Under these conditions a self-contained breathing apparatus is required. **(2) The ordinary gas mask does not afford sufficient protection against heavy concentrations of a fumigant such as might be encountered in a grain bin or atmospheric vault under fumigation.** Most canisters are designed to protect against concentrations of less than 2 percent of toxic gases in the air. In ordinary mill fumigations concentrations heavier than this are not usually encountered. **(3) The life of the canister is limited; it can absorb just so much gas and then must be changed.** A good practice is to discard canisters after 1 hour of actual use in air containing a toxic gas. Each canister should be marked to indicate the total period it has been used.

**Unless a gas mask fits tightly, is free from defects, and does not leak, it is useless.** Before entering a concentration of gas the mask should be carefully fitted to the face and head and tested carefully to see that it is securely fastened and that there are no leaks. On first entering a gas-filled room while wearing a gas mask, particular attention should be paid to see whether the odor of the fumigant can be detected. If any odor is detected, the operator should immediately leave the building and determine the trouble.

**It must also be realized that fumigants can be absorbed directly through the skin. It should not, therefore, be taken for granted that the wearing of a gas mask will afford complete protection. Heavy gas concentrations are particularly dangerous, and care should be taken to avoid exposure to them, even though a mask be worn.**

### SUMMARY OF PRECAUTIONS TO BE OBSERVED WHEN USING GAS MASKS

**1. Make sure that the canister is of the kind designed to protect against the fumigant being used, and that the canister is fresh or has not been used long enough to be inefficient.**

**2. Inspect the gas mask to see that there are no leaks or defects, that the canister is properly connected, and that the cardboard disc closing the valve at the bottom is removed.**

**3. Do not enter any place where there is likely to be a concentration of over 2 percent of the fumigant in the air, or where the oxygen has been displaced.**

**4. Do not stay in a heavy concentration of gases such as hydrocyanic acid for more than a brief period, because of the danger of absorbing the poison through the skin.**

## First Aid

**In case of poisoning by toxic gases or asphyxiation due to lack of oxygen, a doctor should be summoned as quickly as possible.** Forbes and Grove [4] suggest the following treatment:

**1. Remove the victim to fresh air as soon as possible.**

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[4] Forbes, J. J., and Grove, G. W. PROTECTION AGAINST MINE GASES. **U. S. Bur. Mines Miner's Cir. 35, 52 pp., illus. 1937.**

**2. If breathing has stopped, is weak and intermittant, or is present in only occasion gasps, artificial respiration, preferably, by the prone-pressure method, should be given persistently until normal breathing is restored or until it is definitely believed that the heart action has stopped.**

**3. Circulation should be aided by rubbing the limbs of the victim and keeping the body warm with blankets, hot-water bottles, or hot bricks.**

**4. It cannot be emphasized too strongly that inhalation of pure oxygen or 5 to 7 percent of carbon dioxide and 95 to 93 percent of oxygen, beginning as soon as possible and continuing for 20 to 30 minutes in mild cases and as long as 1 to 2 hours, if necessary, in severe cases, will greatly reduce the severity of carbon-monoxide poisoning and decrease the possibility of serious after effects. This treatment will also be helpful in gas poisoning or asphyxiation.**

**5. The victim should be kept at rest, lying down to avoid a strain on the heart; later he should be given plenty of time to rest and recuperate.**

## General Considerations

Success in the fumigation of any building depends on the proper preparation of the building itself, the choice of the fumigant, its proper application, and favorable weather conditions. Since insects are more susceptible to fumigants when temperatures are high and fumigants are correspondingly more active and efficient, it is desirable to fumigate when the temperature is at least 75° F., and preferably higher. If possible the fumigation should be conducted at a time when there is little or no wind, since a heavy wind will cause the fumigant to drift over to one side of the building, leaving an inadequate concentration in the other part of the mill.

It is desirable to obtain the maximum concentration of a fumigant in a building at the earliest possible moment, and the gas should be applied in such a manner as to gain this end. If the concentration builds up slowly, the natural leakage from some buildings may be great enough to prevent an effective concentration from ever being attained.

**Before starting to fumigate, police and fire departments should be notified in order to prevent serious accidents in the event that fire should break out while the mill or warehouse is under fumigation. In most large cities a permit must also be obtained. The entire mill must be searched to make certain that no visitors or workmen are still on the premises, all entrances must be locked and placarded with warning signs, and, if located in a congested business area, adjoining buildings should be vacated.**

**After the fumigant has been introduced, a watchman or watchmen should be posted to prevent the entry of people unacquainted with the fact that the building is under fumigation.**

**At the end of the exposure period the building under fumigation should be thoroughly ventilated by opening doors, windows, and ventilators. This is usually accomplished by men wearing gas masks, although in some cases arrangements can be made to open doors and windows from the outside. In all fumigation operations it is well to have men working in pairs so that in case of accident to one man the other may be able to save his life. Aid given at the right time will prevent many possible fatalities. During the ventilation of a building curious persons are likely to attempt to see what is going on and at this time watchmen must be particularly vigilant to prevent unauthorized people or workmen from entering until all danger from the fumigant has been removed.**

## PREPARATION OF THE MILL

### SEALING

The effectiveness of a fumigation depends largely on the tightness of the building. Instead of each floor being fumigated separately, the entire mill should be considered as one unit, because inspection and observation after fumigation have shown that many insects are able to survive in the sacking or other material used to plug openings running from floor to floor. All windows should be tightly wedged or sealed, and any broken panes should be replaced. Loosely fitting window sashes should be sealed with paste and paper, or "puttied up" with flour and oil mixed to the consistency of putty. For stripping window frames that are only slightly loose, several types of material, such as rolls of gummed paper, strips of newspaper smeared with grease or pasted with flour paste, or rolls of unsterilized adhesive tape, can be used. When it is impossible to tighten a window by the ordinary method of sealing or stripping, it is necessary to seal the entire aperture. For this purpose car-lining paper can be used.

Small doors leading to the exterior of the building can be tightened with any of the materials used for the windows. Large sliding metal or wooden doors that fit imperfectly can be calked up with the flour-and-oil mixture or with a paste composed of 4 parts of asbestos to 1 part of calcium chloride mixed with a little water. Either of these mixtures will form an effective seal yet can be easily removed after fumigation.

For sealing ventilators, three thicknesses of heavy paper, covered with sacking or canvas and well pasted and tied, are often used when these are sealed from the roof. Some ventilators are more easily sealed from the settling chamber below the ventilator. Wherever possible, it is desirable to remove the mushroom-shaped cap of the ventilator and replace it with a metal cap, which fits the ventilator pipe snugly.

### CLEANING OPERATIONS

#### BEFORE STOPPING THE MILL

1. Shut off feed (wheat) at mixing bin.
2. Continue running all machinery until material is emptied from spouts, elevators, rolls, sifters, reels, purifiers, feed dusters, suction trunking, and dust collectors.
3. Remove elevator-boot slides and station men along the boots to keep stock pulled out where belt cups will not carry it up in its natural course.
4. Meanwhile hammer elevator legs, machinery, frames, tubular dust collectors, and spouts with a rubber mallet or other device which will not bruise or injure the equipment.

#### AFTER STOPPING THE MILL

1. Start the entire clean-up crew at the top of the mill and work downward.
2. Open all machines, conveyer boxes, and flour bins.
3. Clean out suction trunks, conveyors, and dust-collector systems.
4. Examine settling chambers of dust collectors and clean out all accumulations.
5. Open dust collector, back drafts, main trunks, and hand openings.
6. Loosen all sifter doors to permit entrance of gas during fumigation; remove sieves and stack same on the floor.
7. Clean out accumulations from bottom section of the bran duster.
8. Remove covers of all conveyers, making certain that all dead-end spaces are readily accessible.
9. Thoroughly clean all conveyers, including dead-end spaces.

10. Remove adjustable feed gage above grinding rolls and clean out accumulations above rolls and feeders.
11. Leave every machine open; also all hand openings to spouts, elevator legs, and similar places.
12. Particular attention should be given to the cleaning out of dead spouts or conveyers.
13. Remove accumulations of stock from elevator boots.
14. Remove to the fumigation vault all infested materials accumulated in cleaning the mill.
15. If the foregoing procedure is followed, no accumulation of more than 1 inch in depth will be present in the mill.
16. Special attention should be given to the cleaning of the dead spouts and dead spaces in corners of spouts and machines.
17. Remove all bags or other materials used to plug spouts.
18. Seal roof ventilators or replace mushroom-shaped caps with a tight metal cap.

## Fumigation With Hydrocyanic Acid Gas

Hydrocyanic acid has been the standard fumigant for flour mills for many years. It is particularly well adapted for this type of work because many mills are not built to hold a gaseous fumigant for any extended period and only a gas that acts quickly can be effective. Hydrocyanic acid gas kills with great rapidity; therefore, notwithstanding the fact that all the gas may be lost in a short time, a nearly perfect kill may have been obtained.

Many methods of fumigating with hydrocyanic acid have been developed, all of which have their application. Of the various methods of generating the gas, that of vaporizing liquid hydrocyanic acid is used the most extensively.

### LIQUID HYDROCYANIC ACID

Liquid hydrocyanic acid (96–98 percent HCN) is marketed in cylinders ranging in capacity from 30 to 75 pounds. There are several ways in which liquid hydrocyanic acid can be used, all of which are effective.

#### OPEN-SPACE APPLICATION

The method by which liquid hydrocyanic acid is most commonly used in the United States consists of forcing it into the open space of a flour mill through a system of metal piping equipped with spray nozzles. The cylinders containing the gas are attached to a manifold on the outside of the building and the fumigant is forced into the piping system by means of compressed air (fig. 19).

#### *Piping the mill*

In mills fumigated by the liquid method a permanent system of piping is often installed. Either brass or copper piping is recommended. Iron piping is less expensive, but because of its tendency to rust and cause clogging of the spray nozzles it is less desirable. A flexible copper tubing three-eighths of an inch in diameter costs about 6 cents a foot. Since it can be readily bent, elbow fittings are unnecessary, and compression couplings can be used, except at the main inlet, where the cylinders are connected.

In normal times most mills can be piped with copper tubing at a cost of 10 to 13 cents per 1,000 cubic feet of space, including cost of

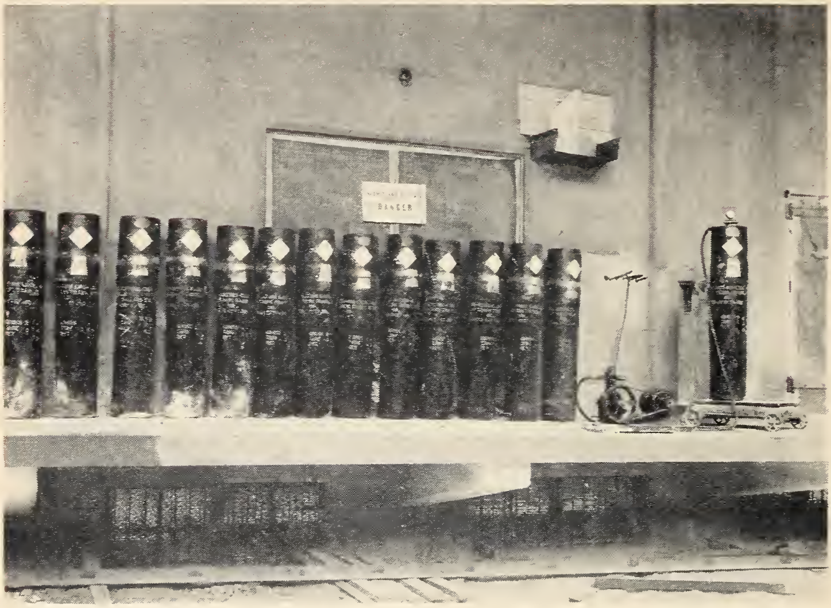

FIGURE 19.—Liquid hydrocyanic acid being pumped into a flour mill undergoing fumigation.

material and installation. Brass tubing costs about two and one-half times as much as copper. During wartime the cost of piping a mill will be much higher. Commercial fumigators are usually equipped with sufficient reinforced rubber hose so that they can introduce the liquid hydrocyanic acid through hose if a piping system has not been installed. The hose is laid on the floors of the mill and spray nozzles are connected in whenever desired. A line of hose is run from each floor to a point outside the building where it can be connected to a cylinder of gas.

In large mills with several floors, where numerous branch lines are used, each floor should be provided with a separate riser. At least one spray nozzle should be provided for every 10,000 cubic feet of space, and it is generally advantageous to use more than this. The piping system should be so arranged that the pressure of the gas will be approximately the same at all nozzles, thus insuring an even distribution of the gas. Each riser is connected with a special inlet pipe leading through the outside wall of the building.

Piping plans are usually designed by an employee of the fumigating company after he has made a survey of the building. Should blueprints of the mill or rough sketches and measurements be forwarded to one of these companies for making piping plans, special attention should be given to showing offsets and whole or part partitions. Any other special condition, such as heavily infested machinery, rows of packing machines, or other places of heavy infestation, should be noted in order that an extra spray nozzle may be added at this point if it is thought advisable. There should not be more than 10 spray nozzles to each riser. Where grain or flour bins are piped, a separate riser for these bins should be used.

**Reinforced rubber hose is used to connect the cylinders to the piping system. This hose must be kept in good condition, since there is always some danger of weakened hose bursting under pressure and showering the operator with the deadly fluid.**

**Before the material is applied, care should be taken that all connections outside the building are tight. Should a leak develop from a loose connection where the hose from the cylinder is attached to the piping, such connection can be tightened with reasonable safety if the operator wears a gas mask and is careful that the liquid does not spray his clothing. If the pipe wrench is operated with the handle above the connection instead of below it, the material will not run down the handle onto the arms and clothing. If in doubt whether the spray has reached the clothing, or if the liquid has run down the arms and possibly onto one's shirt or coat, the shirt or coat should be removed and the hands and arms washed *before the mask is removed.***

### *Applying the Gas*

Each cylinder of liquid hydrocyanic acid is supplied with an inlet and an outlet valve. The outlet valve is attached to a steel tube connected with the bottom of the cylinder. The inlet valve leads directly into the top of the cylinder, and through it air is pumped by means of a compressor, until a pressure of about 100 pounds is obtained. The outlet valve, which in the meantime has been connected with the inlet pipe to the building, is then opened and the liquid is forced into the building. The pressure must be maintained until all the liquid has been blown through the pipes into the building. The pipe-lines are then blown clear and the inlet pipes capped.

### *Removal of Spray Nozzles*

After the fumigation and after the building has been well ventilated, the spray nozzles should be removed for storage and the pipes should be capped. **While removing spray nozzles the operator should take care to prevent any liquid, which sometimes remains in the pipe, from dropping onto the face or other parts of the body. He should never stand directly under the nozzle while removing it. Should any liquid hydrocyanic acid be lodged behind the nozzle, a decided cooling effect will be noticed while the nozzle is being unscrewed. It is best to use a gas mask in this work.**

Special pressure nozzles which do not clog and need not be removed are now on the market.

### *The Dosage*

The dosage will depend on the construction of the mill and the degree of penetration desired. In general, 8 ounces of liquid hydrocyanic acid for each 1,000 cubic feet of space will give excellent results. Ordinarily the gas is evenly distributed on all floors, but a larger quantity should be used on floors that contain more machinery than others.

Recent experimental work has shown that if the mill is of modern concrete or brick construction much of the labor of preparing the mill for fumigation may be avoided by increasing the dosage to 16 ounces per 1,000 cubic feet of space. Aside from sealing up the building and opening up the machinery according to directions, no other preparations are necessary. The extra gas introduced will ensure the penetration of stock in the various milling units.

### *The Machinery-Piping System*

A refinement in the fumigation of flour mills with liquid hydrocyanic acid consists in applying the liquid fumigant directly into the milling units by means of a series of pipe lines (figs. 20 and 21). By utilizing spray nozzles that open when a uniform pressure is obtained throughout the system, equal quantities of fumigant are supplied to each milling unit. The spray nozzles are so constructed that when the pressure is removed a flexible diaphragm recoils, the holes in the diaphragm through which the fumigant is discharged being closed by a central pin. This prevents foreign matter from plugging up the nozzles between fumigations. As is the case with the open-space system, the gas is applied from outside the mill. A considerable saving in cost is effected by using this method, since a much smaller quantity of gas is required to produce a very high concentration in the milling units, where most of the insects in the modern mill are to be found. Furthermore, by this method it is unnecessary to dismantle and clean out the machinery. It is estimated that the saving in labor and shutdown time, together with the saving in fumigant required, will allow two fumigations for the same cost as one by the open-space method. It is considered that enough gas will escape from the machinery to care for any insects that are in the open space of the mill. In old wooden mills it has been found that the woodwork often harbors large numbers of insects, not all of which are reached by the gas when it is applied by the machinery-piping system. For this type of mill the open-space method of fumigation would probably be more satisfactory.

### *Preparing the Mill*

Before the mill is shut down the same preparations should be followed as suggested for open-space fumigation; however, it is not necessary to clean out and open up the machinery. Directions for preparing the mill after it is shut down follow:

1. Start the entire clean-up crew at the top of the mill and work downward. Do not have men working on several floors at the same time.

2. The roof ventilators from cyclone dust collectors must be sealed tightly because they are directly connected with practically all milling equipment. Proper sealing of roof vents is essential to the success of any fumigation. The best method of sealing roof vents is to remove the mushroom-shaped caps and replace them with tightly fitting metal caps or covers, which should be provided in advance of the fumigation date. Covering vents with paper or combinations of paper, burlap, or tarpaulins is not entirely satisfactory and is not recommended, but may be effective if carefully done.

3. Sifter doors (except Wolf sifters) should be loosened slightly to allow circulation of gas into all sifter sections.

4. Accumulations of milling stock behind feed gates or purifiers should be removed and the feed gates either tied or blocked open to allow passage of gas into slide spouts which carry stock into the purifiers. Purifier ventilator doors should be sealed with Kraft paper.

5. Dividing gates, or tips, below the cant boards in reels and purifiers should either be adjusted so that they are vertical or so that half will be open one way and half open the other way. This is essential in order that there may be equal distribution of gas into all the conveyors. Stock accumulations in reel and puri-

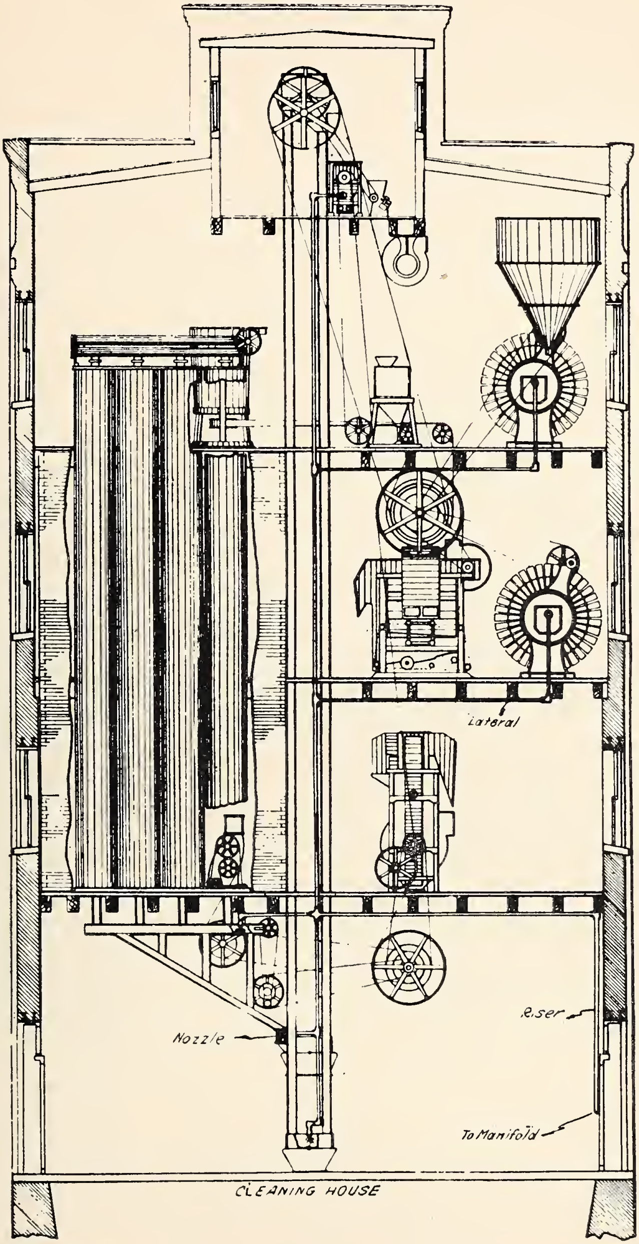

FIGURE 20.—Method of piping machinery in a flour mill for fumigation with liquid hydrocyanic acid. Cleaning house.

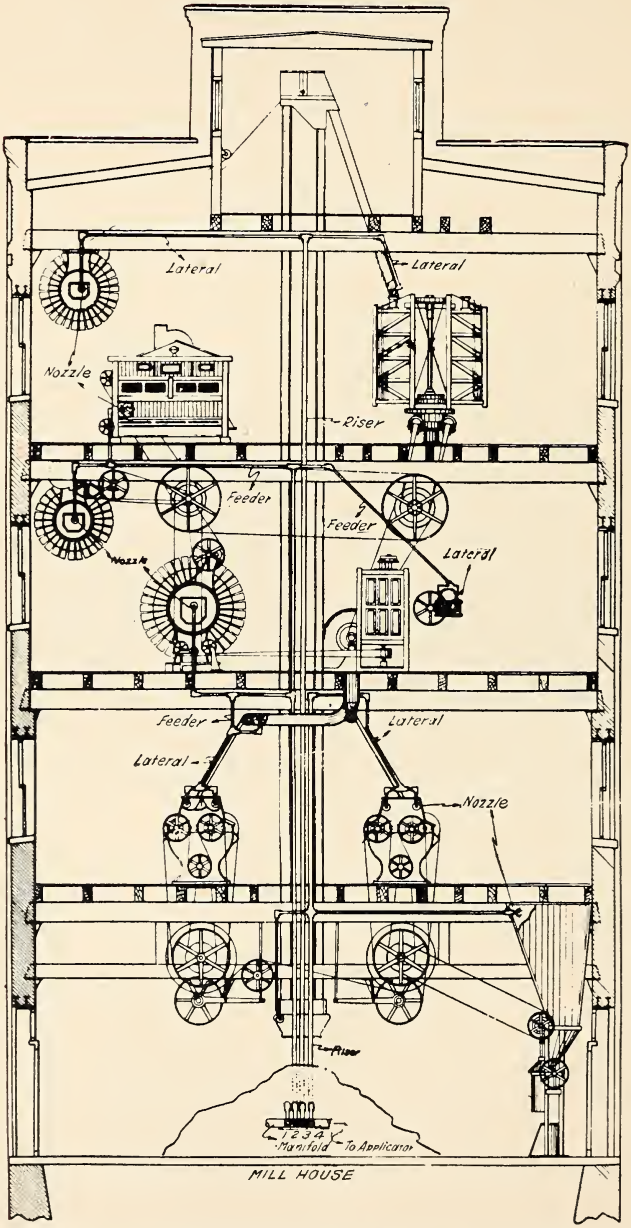

FIGURE 21.—Method of piping machinery in a flour mill for fumigation with liquid hydrocyanic acid. Mill house.

fier-conveyer ends beyond reach of the flights should be removed, together with any packed accumulations more than 3 inches deep. Reel and purifier-conveyer housing covers should be kept closed.

6. Accumulations of stock above the roll feed gate should be removed. Roll housings should be cleaned, the feeder gates blocked open, and all housing doors closed.
7. Hand levers of Buckley grinders should be raised, thus compressing driving springs and separating grinding surfaces to permit passage of gas through the mechanism.
8. Splitter valves on slide spouts should be placed on center to eliminate possibility of dead-air spaces.
9. Remove accumulations of stock from boots, then close all boot slides. It is best to leave this operation until other clean-up operations have been completed.
10. Check all milling units to see that all have been prepared as herein recommended.
11. Stock removed from elevator boots or other milling equipment should be bagged and either placed in a fumigation vault for treatment or otherwise disposed of outside the mill building. Do not return such stock to the mill after the fumigation.
12. Windows and doors should be closed but need not be sealed. Broken window sash should be replaced.

Before fumigation, air pressure should be applied to the piping system and each spray nozzle examined to see that it is working properly. Leaky connections should be tightened. The care expended in keeping the lines and nozzles clear of deposits will be a big factor in the success of fumigations by this method. Lines should be blown clear of the liquid fumigant after each fumigation.

### *Applying the Gas*

In introducing the liquid hydrocyanic acid into the various milling units it is necessary to force the gas into the fumigation lines with sufficient pressure to ensure a uniform distribution. As the standard hydrocyanic acid cylinder has too small an aperture to allow this, it is necessary to employ a special applicator consisting of a small steel tank holding 35 pounds of the liquid and capable of withstanding a working pressure of 200 pounds. The gas-outlet valve on the top-central part of the cylinder is connected with a ½-inch copper tube extending to the bottom of the tank. This tube is larger than that used in the hydrocyanic acid cylinder and permits the gas to flow as rapidly as required. Gas-inlet valves (¼-inch brass) and a pressure gage are also located on the top-central part of the applicator. From the tank connection of the gage a by-pass of ¼-inch copper tubing, supplied with a valve, is connected to the gas-outlet line between the gas-outlet valve and the manifold of the piping system. This bypass allows the pressure created by the transfer of the hydrocyanic acid from the shipping cylinder to the applicator to escape into the manifold, thus facilitating the filling of the applicator.

### *The Dosage*

Liquid hydrocyanic acid is forced into the various lines at the rate of about 8 ounces for each spray nozzle. Some fumigators prefer to use a heavier dosage, but this is rarely necessary.

At the end of the fumigation the mill can be ventilated in the manner employed in other fumigations. Workmen wearing gas masks should open all doors and windows to allow air to circulate through the building. Roof vents should be opened as soon as possible to allow the gas to escape from the machinery.

**To avoid accident from small quantities of fumigant left in the system, compressed air should be forced through all fumigation lines long enough to ensure a complete removal of hydrocyanic acid. This should be done during the ventilation process and before workmen are allowed to enter the building.**

### THE BARREL OR POT METHOD

The open-space fumigation of flour mills was originally accomplished by generating the gas from a mixture of potassium or sodium cyanide with dilute sulfuric acid. This method is known as the barrel, or pot method, because the chemicals used in the process are placed together in a barrel or similar container. Although more laborious than the liquid hydrocyanic acid method, it is considerably cheaper and many millers have learned to use it. It is effective if properly done but is not without danger to the operator. When this method is used, the mill is prepared in exactly the same way as described for the open-space method of fumigating with liquid hydrocyanic acid.

#### CHEMICALS REQUIRED

Sodium cyanide (96 to 98 percent, containing 54 percent of available HCN), a commercial grade of sulfuric acid (66° B.), and water are the only materials required. For best results they should be mixed according to the following formula:

| | | |
|---|---|---|
| Sodium cyanide | 1 | pound |
| Sulfuric acid | 1½ | pints |
| Water | 2 | pints |

Sodium cyanide is a white crystalline substance, which for fumigation purposes is prepared in egg-shaped lumps weighing approximately ½ to 1 ounce each. It is a violent stomach poison, and can also cause serious poisoning if absorbed through open cuts. For this reason it is best handled with a scoop or shovel or with gloved hands.

Sulfuric acid is a heavy, colorless liquid when pure, but the commercial acid used in large-scale fumigation work is slightly discolored, or murky, owing to impurities. It is highly corrosive and will cause injury if it spatters on the clothing or body of the operator or upon the floor. It can be purchased in 11-gallon carboys. When large quantities of acid are required, a tilting frame will be found convenient in pouring the acid from the carboy, or an acid pump can be used.

#### PROPER ORDER OF PLACING CHEMICALS IN GENERATOR

To generate hydrocyanic acid gas by this method, the operator should first pour the water into the generator and then add the acid. If the procedure is reversed, the reaction will be so violent that the operator may be dangerously burned by the spattering of the acid-water mixture.

The addition of the sodium cyanide to the mixture of water and acid causes an immediate chemical reaction in which hydrocyanic acid gas is given off. The pure gas is colorless, but when mixed with steam produced by the chemical reaction it has the appearance of a light-bluish smoke. It has an odor resembling that of peach kernels.

### THE DOSAGE

For general mill fumigation 1 pound of sodium cyanide will produce enough gas to fumigate 1,000 cubic feet of space, if the building is of reasonably tight construction.

### THE GENERATOR

For large-scale fumigation a watertight 50-gallon barrel is the most suitable generator to use. Each barrel will hold a maximum charge of 30 pounds of sodium cyanide, or enough to fumigate 30,000 cubic feet of space. When it is necessary to fumigate small rooms of a few thousand cubic feet of separate units, earthenware or stone jars of appropriate size can be used. A 4-gallon jar will hold a charge of 3 pounds of sodium cyanide.

Each barrel generator should be set in a galvanized-iron washtub in which has previously been placed a pailful of water containing several handfuls of washing soda. This precaution provides for catching and neutralizing small quantities of the acid-water mixture that may leak out of the barrel.

If three or four bricks are placed in the bottom of the washtub for the barrel to rest on, it will not become stuck in the tub.

### PLACING THE GENERATORS

If possible, the generators should be spaced evenly over the floors to obtain an even distribution of the gas. If necessary, however, the generators for one floor can be grouped together near the exit (fig. 22).

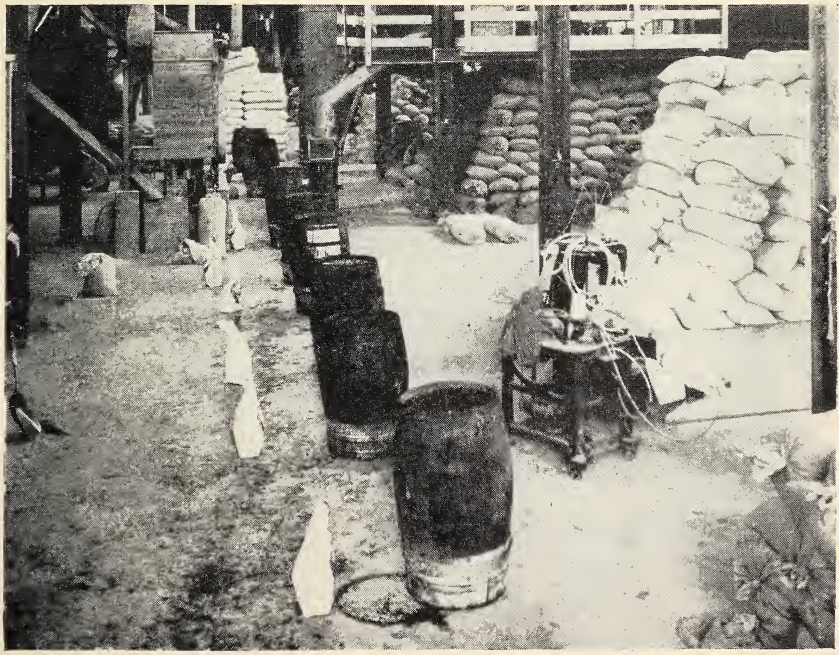

FIGURE 22.—Fumigation of a mill with hydrocyanic acid gas by the barrel method.

The gas will eventually be dispersed to all parts of the enclosed space, though not so rapidly as when the generators are scattered evenly over the floor.

### GENERATING THE GAS

After the mill has been prepared for the fumigation and all the generators have been placed in their proper positions, the water and acid are measured out and distributed. The acid can be poured from the carboys into heavy galvanized-iron buckets, which will resist the action of the acid long enough for it to be distributed without accident. If jars are used for generators, the acid must be poured into the water slowly, lest the heat developed by the chemical reaction between the water and acid cause the jars to break.

After the foreman of the fumigating crew has determined that none of the barrels leak, the sodium cyanide, which has been weighed in the proper quantities and placed in paper bags, should be placed beside the generators.

When all the precautionary measures have been taken, and as soon as possible after the water and acid have been mixed, the fumigating crew should proceed to the top of the building and, starting with the generator farthest from the exit, lower the bags gently into the generators, proceeding downward from floor to floor as rapidly as possible. **The foreman should not take part in the lowering of the cyanide, but should watch the crew to see that none of the generators are skipped and that none of the men get into trouble.**

Since the gas is generated as soon as the acid-water mixture comes in contact with the sodium cyanide, the operators engaged in dropping the cyanide should wear gas masks (fig. 23).

### EMPTYING THE GENERATORS

When the fumigation is finished and the building has been thoroughly ventilated, the residue must be emptied from the generators. Sometimes the chemical reaction is incomplete, because some of the sodium cyanide has not come in contact with the acid-water mixture. **When the generator is moved, the contents are shaken up and small quantities of gas may be given off. For this reason the operator should breathe as little as possible while handling the barrels and should not hold his head over the barrel. The residue, which is poisonous, can be disposed of by pouring it into a hole in the ground and covering it with soil. When disposing of the residual material after fumigation, the operator should never bend over the hole, but should stand to windward and lean away from the hole as much as possible.**

### AUTOMATIC GENERATORS

A variation of the barrel method is obtained by use of a commercially manufactured automatic generator. The sodium cyanide and dilute sulfuric acid are placed in the generator, which automatically generates and discharges hydrocyanic acid. For small mills the generator can be operated outside of the mill and the gas introduced through a pipe or reinforced hose. It has been found that the gas can all be introduced into a lower floor of the mill with satisfactory results,

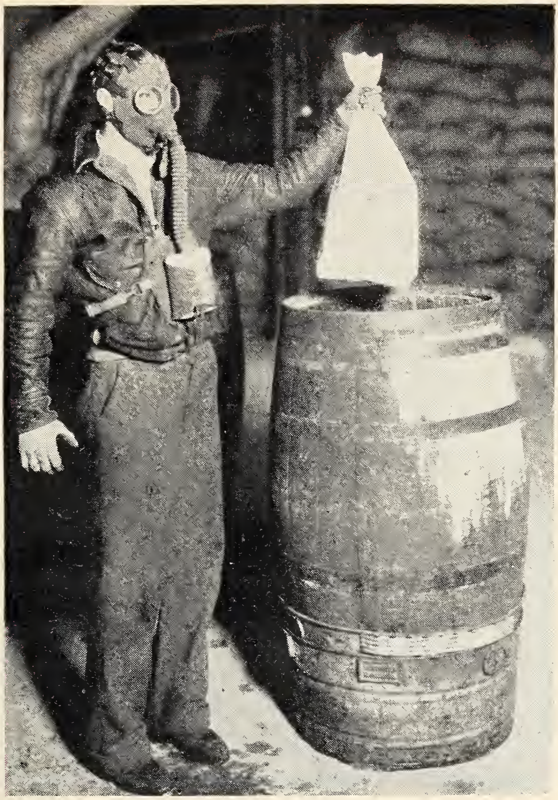

FIGURE 23.—Man, wearing gas mask, about to lower a bag of sodium cyanide into a barrel containing sulfuric acid and water.

the hot gas distributing itself with reasonable uniformity all over the building. Much of the danger of the barrel method can be eliminated by the use of the automatic generator, although it is not entirely free from hazard, and where large quantities of gas are required there is considerable labor attached to emptying and refilling the generators. A generator of either 10 or 25 pounds capacity is simple and, as shown in figure 24, consists of a metal cylinder in which a perforated metal basket slides up and down on a central shaft controlled by the presure developed by the generated gas.

The water and sulfuric acid are poured, *in that order*, into the generator, after which the sodium cyanide is placed in the metal basket, which is held above the dilute acid solution by means of a set screw, until the opening in the top of the generator has been closed and all is ready for the gas to be generated. The basket containing the sodium cyanide is then allowed to slide gently down into the acid. Hydrocyanic acid gas is immediately generated, flows out through an orifice at the top of the generator, and is conducted by means of a hose to the building to be fumigated. Enough pressure is generated to force the gas from the generator into the mill. To prevent any of the sulfuric acid from being carried into the building with the gas, acid separators, which can be purchased with the generator, are connected into the line between the generator and the building. The central shaft, to which the cyanide basket is attached, is so regulated that, when the pressure reaches 5 to 7 pounds, it is forced up, lifting the sodium cyanide out of the acid solution. When the pressure drops the basket slides down into the acid again and the generation of the gas is resumed. The operation is automatic until the gas has all been generated, after which the generator must be emptied and refilled.

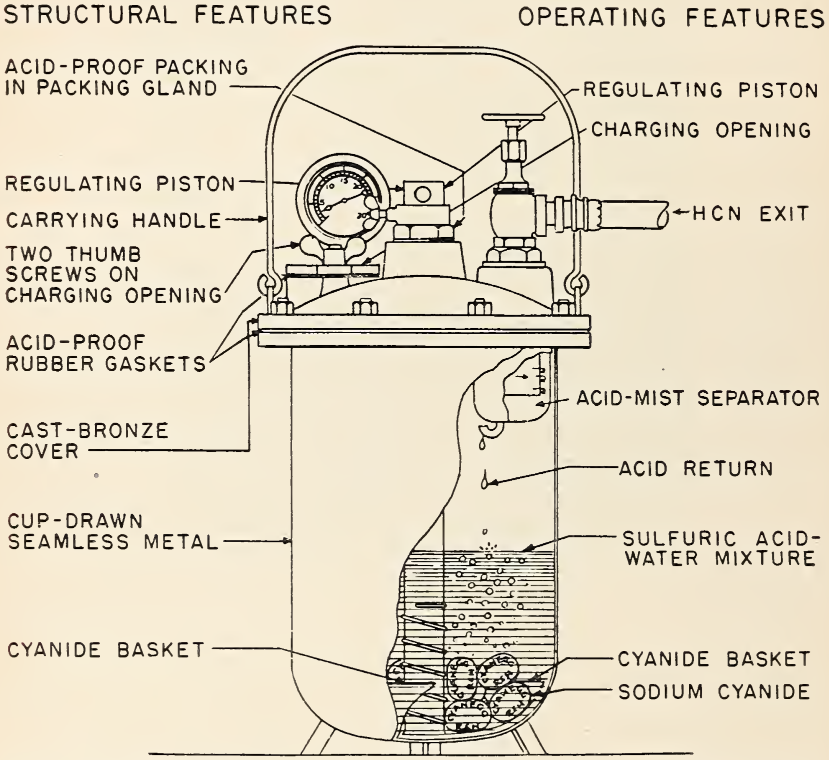

FIGURE 24.—Hydrocyanic acid gas generator showing details of construction and operating parts.

**When the generator is being used, care must be exercised to see that the basket holding the sodium cyanide is held out of the acid until the opening in the top of the generator is closed. If it is allowed to fall prematurely, the generator gas will issue from the opening and endanger the lives of everyone around it.** For fumigating flour mills a generator with a capacity of 25 pounds of cyanide for each filling should be used. It has been found that the following formula is more efficient for use in the generator than the one used in the regular barrel method.

| | |
|---|---|
| Sodium cyanide | 5 pounds |
| Sulfuric acid | 1 gallon |
| Water | 1 gallon |

### CALCIUM CYANIDE METHOD

Although not extensively used in mill fumigation, calcium cyanide in dust form is occasionally used to generate hydrocyanic acid gas. Upon exposure to the air, the powder absorbs moisture and a chemical reaction takes place by which hydrocyanic acid gas is given off. Two forms of calcium cyanide are on the market, one containing 22 to 28 percent of available hydrocyanic acid gas and the other 51 to 52 percent.

One pound of the 51- to 52-percent material, or 2 pounds of the 22- to 28-percent material, per 1,000 cubic feet of space should be used.

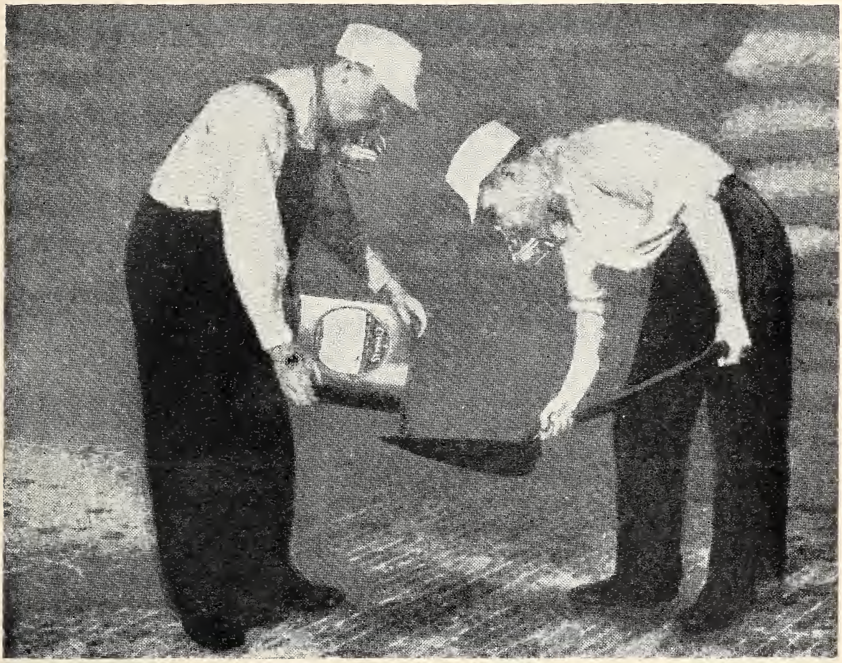

FIGURE 25.—Spreading calcium cyanide in flour warehouse.

The required number of cans of calcium cyanide are distributed about the building. They are then opened and the contents scattered over the floor in a layer not more than half an inch thick. It is desirable to scatter the 51- to 52-percent material on strips of paper previously laid on the floor to facilitate removal of residue after fumigation. The other form is more granular and can be easily swept up.

**The fumigators should begin distributing the dust on the top floor at the point farthest from the exit, so that they will be working away from the gas and toward the exit to the floor below (fig. 25). They should wear gas masks because the dust begins to give off the gas as soon as it is exposed to the air.**

**The residue should be disposed of outside the building as soon as possible after the fumigation, because some hydrocyanic acid gas is likely to be retained.** After all the hydrocyanic acid gas has been given off, the residue is nonpoisonous.

Small quantities of this material may also be used in connection with open-space fumigations with liquid hydrocyanic acid where quantities of less than a full cylinder of hydrocyanic acid are required to complete the dosage.

### THE DISCOID METHOD

Liquid hydrocyanic acid absorbed in an inert material is also useful in the fumigation of certain types of small mills. The inert material is pressed into waferlike discoids each containing approximately one-half ounce of liquid hydrocyanic acid. These discoids are packed in sealed cans of various sizes, and are sold on the basis of net liquid hydrocyanic acid content. **Use of discoids by anyone other than professional fumigators is not recommended.**

When large quantities of discoids are to be used, it is advisable to chill the cans before fumigating. This will retard the evolution of the gas and thus increase the safety of the operation. If solid carbon dioxide is available, a liberal quantity thrown over the tops of the cans in each open case a few hours before the fumigation will chill the discoids.

The proper number of cans should be placed on each floor to be fumigated, and **fumigation should be started on the top floor. Gas masks must be put on before the cans are opened, and worn throughout the fumigation.** One man should open the cans (fig. 26), using a special can opener that makes a clean cut close to the

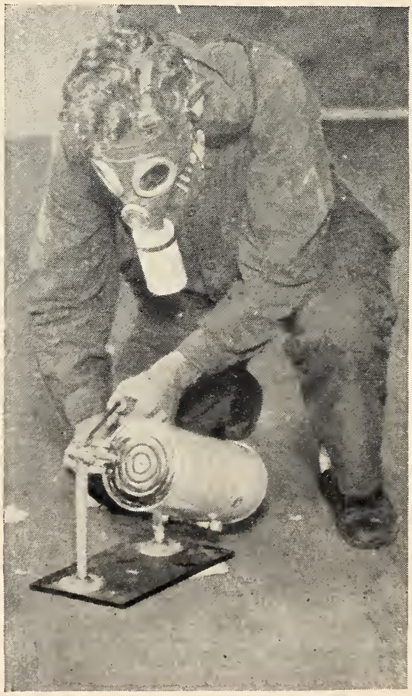

FIGURE 26.—Man, protected by gas mask, removing the top from a tin can containing discoids impregnated with liquid hydrocyanic acid.

rim, while two or more men take the open cans and scatter the discoids over the floor or among the machinery.

*Discoids should not be placed directly on painted or varnished floors or woodwork, for the liquid hydrocyanic acid is likely to injure the finish.* A layer of two or three thicknesses of paper will provide adequate protection against any liquid that may ooze from the discoids.

**When discoids are used, the fumigators are exposed to the gas while they are opening the cans and distributing the contents. Good gas masks will protect them against breathing poisonous fumes, but there is also some danger from the direct absorption of hydrocyanic acid gas through the skin. The fumigating crew should be large enough so that the distribution of the fumigant will be speedy and no one man will be exposed to the gas for a dangerously long period.**

As in the case of liquid hydrocyanic acid, a dosage of 8 ounces per 1,000 cubic feet of space should be used.

After the fumigation and ventilation of the building, the spent discoids and the empty cans can be gathered and disposed of by burning them or by burying them in the ground. At the end of a 24-hour fumigation the discoids will not retain more than a trace of hydrocyanic acid.

## Fumigation With Methyl Bromide

For the fumigation of modern, tight, concrete, stone, or brick mills, methyl bromide has been found highly efficient. It is not recommended for use in mills of wood, or of frame and sheet-metal construction, owing to the difficulty of holding the vapors long enough to obtain a satisfactory kill.

A special sealing technique is required for making this type of building tight enough for methyl bromide fumigation that is ordinarily too costly to be employed.

### PROPERTIES OF METHYL BROMIDE

Methyl bromide is a colorless gas which boils at 40.1° F. At ordinary room temperature it is a gas weighing 0.247 pound per cubic foot. It is obtainable commercially in liquid form in 1-pound cans or in cylinders containing 10, 50, or 175 pounds net. The natural pressure of the gas is sufficient at room temperature so that both cans and cylinders are self-emptying when opened. The pressure in the cylinders, however, is increased slightly by the manufacturers to facilitate the rapid removal of the gas.

Methyl bromide is relatively inexpensive at the dosages required for fumigation, highly toxic to all stages of insects including their eggs, noninflammable at concentrations used in commercial practice, and can be used successfully at comparatively low temperatures. It has remarkable powers of penetration and is undoubtedly the most efficient fumigant known for the treatment of warehouses filled with bagged commodities. **Lacking a distinctive odor, this gas is but faintly noticeable in small amounts, a feature that creates a hazard not present with some of the rapidly toxic gases that possess distinctive warning properties.**

**All persons using methyl bromide as a fumigant and all persons engaged in unloading or removing fumigated materials from cars, sheds, or rooms in which commodities have been fumigated should be warned of the toxic properties of methyl bromide. The dangers from inhaling the gas and the absence of odor should be stressed. Although methyl bromide is less toxic to man than certain other fumigants, all persons fumigating with methyl bromide or mixtures containing methyl bromide, or persons entering fumigated rooms, cars, or sheds to open ventilators or to unload fumigated materials, should observe the same precautions as with other fumigating gases. The following precautionary measures are recommended in the use of methyl bromide as a fumigant:**

**1. Avoid breathing air containing methyl bromide by wearing a gas mask at all times when handling the fumigant outside the original container.**

**2. Provide in advance for thorough ventilation of cars, rooms, or buildings after fumigation, before anyone enters them.**

**3. When necessary to enter spaces containing methyl bromide, use a gas mask provided with a canister giving protection against organic vapors, or a positive pressure-hose mask. (Masks and canisters to be approved under U. S. Bureau of Mines Schedules 14D or 19A. Canisters to be black, type B. Workers should be provided with these approved masks for use when necessary in handling this fumigant or commodities that have been fumigated with it. All mask canisters have a limited life period. For this reason special precautions should always be taken to see that masks are fitted with fresh or fully effective canisters. )**

**4. Avoid spilling methyl bromide. In case of spillage go into the fresh air immediately, and remove any clothing that has become impregnated with the liquid.**

**5. Post signs warning that methyl bromide is being used and that the gas is poisonous.**

**6. Store containers of methyl bromide in a cool, well-ventilated place, well removed from any buildings in which people work or live. Avoid leakage by seeing that valves on cylinders are tightly closed.**

## PREPARING THE MILL

In preparing a mill for fumigation with methyl bromide the entire building should be closed as tightly as possible; all windows should be tightly wedged and sealed and any broken panes replaced; loosely fitting window sashes should be sealed with paste and paper or "puttied up" with a mixture of flour and oil; doors should be sealed in a similar manner. Whenever paper is used for sealing purposes it should be coated with ordinary lubricating oil, because it has been found that methyl bromide vapors will not pass through paper so treated, whereas they will escape through ordinary paper. In addition—

1. Open all machines, conveyer boxes, and flour bins, and all repair openings to spouts, elevator legs, and similar places, and wedge open all feeder gates on rolls and purifiers.

2. Remove covers of all conveyers, making certain that all dead-end spaces are readily accessible.

3. Open dust collectors, back drafts, main trunks, and air-inlet regulators.

4. Remove all sifter doors to permit entrance of gas during fumigation; remove sieves and stack them on the floor.
5. Seal roof ventilators and replace mushroom-shaped caps with a tight metal cap.
6. Do not remove accumulations of stock from elevator boots or milling units.

Each floor, so far as practical, should be treated as a separate unit, by closing doors between floors and to stair wells and freight elevators, although some interchange of gases will necessarily take place through the slide spout and elevator legs.

### METHODS OF APPLYING THE GAS

Methyl bromide can be applied through a piping system in much the same manner as that described for liquid hydrocyanic acid or by releasing the gas directly into the open space from cylinders placed at strategic points in the mill. Each cylinder of methyl bromide is equipped with a siphon tube so that it can be emptied without inverting the cylinder.

If the gas is to be introduced into a mill through a piping system, the pressure in the cylinders should be increased with compressed air to 150 pounds. The cylinder or cylinders are then connected by the single outlet to the manifold of the piping system on the outside of the building. After the valve is opened, the pressure forces the fumigant from the cylinder into the fumigation lines at the rate of about 10 pounds per minute. In cool weather the pressure in the cylinder must sometimes be built up with compressed air a second time to speed up the emptying of the cylinder and the application of the gas. A three-way connection between the cylinder, the manifold, and the air compressor will facilitate this operation. For large mills, where this method of applying the gas is best adapted, the 175-pound cylinders will be found most convenient.

Small mills that do not have piping systems can be fumigated by distributing the requisite number of cylinders uniformly over the several floors and releasing the gas by opening the valves (fig. 27). The smaller cylinders will be found most useful for the purpose and will enable the fumigator to distribute the gas uniformly over the building. One-pound cans can be used to supplement the dosage and are particularly useful for treating small rooms that are cut off from the regular mill space. Each floor of the mill should be provided with large portable fans, which should be operated for at least 1 hour after the gas is introduced, in order to ensure a proper distribution of the gas.

**In applying the gas, the fumigator must be careful not to expose himself to the concentrated vapors, and for his protection he should be supplied with a gas mask equipped with a black canister designed to protect against organic vapors.** If the gas is applied from the outside of the building it is not necessary to wear a gas mask unless the manifold or cylinder connections are leaky, although the mask should be kept handy for use in case of emergency. **Where the cylinders are discharged directly into the open space of the mill, the fumigator, starting from the top of the mill, should proceed from floor to floor, opening the valves of the cylinders by hand and discharging any 1-pound cans required. Two men wearing gas masks should work together and should release the**

**gas as rapidly as possible so that they will not be exposed to a heavy concentration of the fumigant, which might be hazardous even though they are protected by masks.**

A dosage of 1 pound per 1,000 cubic feet of space has been found adequate for the fumigation of all well-constructed mills.

An exposure period of from 16 to 24 hours should be allowed, after which the building may be opened up for aeration. The same precaution should be taken in ventilating the buildings as when hydrocyanic acid or other toxic gas has been used.

**Workmen entering the building to open the windows and doors must wear gas masks equipped with black canisters.** Under ordinary conditions, a mill that has been fumigated with methyl bromide will air out rapidly after it is opened up.

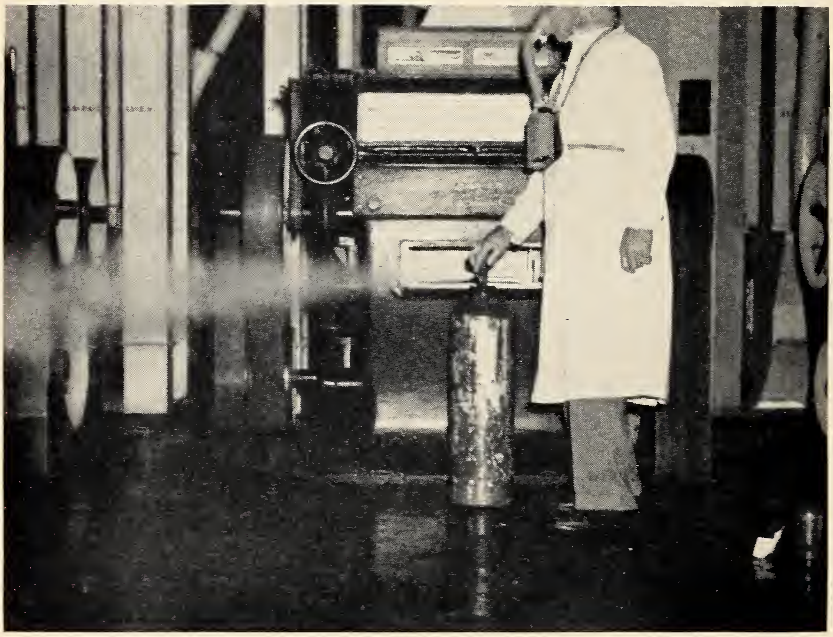

FIGURE 27.—Applying methyl bromide in a flour mill.

## FUMIGATION WITH CHLOROPICRIN

Chloropicrin is used to some extent for the fumigation of flour mills, with excellent results, both by a modified system of the open-space method, together with individual treatment of the milling units, and by introducing the liquid through a piping system directly into the machinery. A mill is prepared in the same way as for fumigation with hydrocyanic acid. For fumigating by the first method a definite quantity of the chloropicrin is introduced by hand into each milling unit and, in addition, 1 pound of the liquid is applied to the open-mill space for every 1,000 cubic feet. The manufacturers of chloropicrin recommend that the individual milling machines be treated with the following dosages:

## DOSAGE TABLE FOR TREATING MILLING MACHINERY WITH CHLOROPICRIN[1]

(9¼ fluid oz.=1 lb.; 1 qt.=3½ lbs.)

| | | |
|---|---|---|
| Sifters | 2–3 ounces each section | Into spout above at most convenient point. |
| Reels and purifiers | 5–6 ounces | 1–2 ounces in each conveyer, remainder inside cover cloth and at ends. |
| Dust collectors | 8–10 ounces | Apply inside and sprinkle between stockings. |
| Conveyors | 1 ounce each 5 feet of length. | Apply at several convenient locations, directly or through spout above. |
| Dusters | 5–6 ounces | Apply inside. |
| Rolls | 1 ounce each | Usually unnecessary to treat. If desired, apply above feeder or into spout above. |
| Bins and scales | 1 ounce per 100 cubic feet | Apply inside. Empty, and close with a few pounds of stock drawn up against bottom of tube. |
| Separators | 2–3 ounces | Apply inside. |
| Elevator legs | 8–10 ounces | Apply through window on upside. Treat last. Sprinkle lightly between legs on each floor and around boots. |

[1] Run all machines 2–3 minutes after application.

The proper quantity of chloropicrin for each floor of the mill should be measured out from the 100-pound cylinders into 1-quart glass bottles or 1-gallon containers, and should be distributed before the fumigation is started. **For the comfort of the workers the measuring should be done outside the building so that the fumes will be dissipated in the open air.** The quart bottles should be graduated so that the correct dosage for each piece of machinery can be applied quickly. One pound of chloropicrin equals 9¼ fluid ounces.

The fumigators start at the top of the mill and work down, treating all machinery, and leaving the elevator boots until the last. **Each fumigator must wear a mask equipped with a canister specially adapted to protect against the vapors of chloropicrin.** The machinery is treated by sprinkling it from the quart bottles directly inside each machine (fig. 28) or, if this is impractical, by pouring it in through a hole bored in one end. Aluminum sprinkler corks can be attached to the quart bottles as they are used. In open-mill space the chloropicrin is sprinkled on burlap sacks spread out on the floor, 6-quart sprinkling cans being convenient for this purpose (fig. 29). **Care should be taken not to spatter the liquid on the hands or feet, since blistering of the skin may result.**

Where conditions in the mill do not warrant a general fumigation, satisfactory results can sometimes be obtained by fumigating the machinery only. For this type of fumigation the chloropicrin is applied directly into the machines in accordance with the dosage table, and the machines are then closed up. The procedure is the same as in the general mill fumigation, except that the machinery is not dismantled and the clean-up of accumulated flour in the machinery need unit and, in addition, 1 pound of the liquid is applied to the open mill space for every 1,000 cubic feet. The manufacturers of chloropicrin recommend that the individual milling machines be treated with the machine.

Considerable time is required to ventilate a building that has been fumigated with chloropicrin, as evaporation is slow and the fumigant clings to fumigated commodities with great tenacity. When present in flour chloropicrin has a deleterious effect on its baking qualities, but this effect disappears when the flour is aerated.

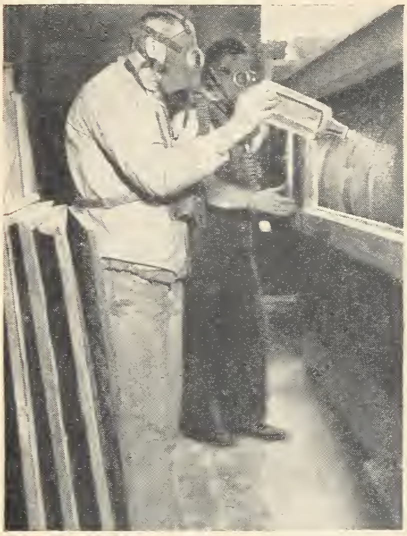

Figure 28.—Treating a purifier with chloropicrin.

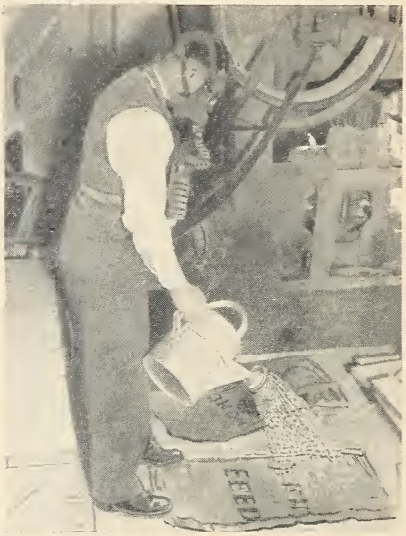

Figure 29.—Applying chloropicrin with a sprinkling can to open-mill space.

### INTRODUCING CHLOROPICRIN BY USE OF A MACHINERY PIPING SYSTEM

The labor of introducing the chloropicrin into the milling machinery by hand can be avoided by piping the elevator heads and forcing the fumigant into the milling machinery with compressed air. By using risers of 2½-inch galvanized pipe, laterals of ½ inch and ⅜-inch pipe, and connecting leads of ¼-inch copper tubing, the chloropicrin is conducted to spray nozzles set in the elevator heads. The risers lead to a tank holding the chloropicrin, which in turn is connected with a compressed-air tank. A working pressure of from 35 to 50 pounds is used to inject the fumigant.

By modification of this system all milling units can be supplied with the fumigant. The mill is prepared for treatment in much the same way as it would be for the machinery-piping system when liquid hydrocyanic acid is used. The mill is run at half speed while the gas is being introduced and for an additional few minutes to promote a good distribution of the gas. The usual precautions are necessary to safeguard the operator as in all fumigations with chloropicrin. After the mill has been opened for ventilation in the usual manner, the mill should be run empty for about 20 minutes to help clear the system of the gas. A dosage of approximately 90 pounds of chloropicrin is required to fumigate a mill of 1,000-barrel capacity.

## Local Fumigation

The treatment of an individual machine in a mill with a fumigant is referred to as a local fumigation. After a general fumigation in which a large proportion of the insect population of a mill is eliminated, it is only a matter of time before some of the milling units becomes reinfested from individual insects surviving the fumigation, or through one or more of the avenues by which insects enter the mill. By the proper use of local fumigants much good can be done in keeping down these infestations to a point where they will not be a serious factor. This is particularly true in modern concrete mills where insects cannot find refuge in old woodwork. Some mills rely on periodic local fumigations instead of an occasional general fumigation. Such a fumigation program will not be so successful in an old wooden mill, since the insects becoming established in the woodwork will not be affected by local fumigants and will continually reinfest the machinery. Local fumigations can be conducted on week ends or any night after the mill is shut down. For best results they should be given every 3 or 4 weeks. Chloropicrin, hydrocyanic acid, and the ethylene dichloride-carbon tetrachloride mixture are used extensively for this purpose.

Chloropicrin is used in local fumigations in the same way as described for general fumigation, except that the machine to be treated is sealed off from the others. **The fumigator should, of course, wear a gas mask.**

The ethylene dichloride-carbon tetrachloride mixture is applied by spraying or pouring it into the individual units at the following dosages:

| | |
|---|---|
| Purifiers and reels | 16–20 ounces in each conveyer. |
| Sifters | 12 ounces in each section. |
| Flour conveyers | 1–2 ounces per linear foot. |
| Elevator boots | 12 ounces. |
| Elevator heads | 12 ounces to each leg. |

Other machinery in proportion to size.

Hydrocyanic acid can be applied in several ways. Calcium cyanide containing from 22 to 28 percent of available hydrocyanic acid is frequently used for this purpose and is easily applied. A dosage of about 12 ounces for each machine is applied to rolls, purifiers, and sifters. It is spread evenly on dry newspapers in the lower part of the machine (fig. 30). If sifters are equipped with blanks, they should be removed from one section or opening to allow free circulation of the gas. Two ounces of the calcium cyanide should be used for each elevator leg on each floor.

## HEAT TREATMENT

The effectiveness of heat in the control of all insects infesting flour mills was first determined as a result of investigations conducted by G. A. Dean from 1910 to 1913. Following experimental work at the Kansas Agricultural Experiment Station, Manhattan, Kans., practical demonstrations were conducted in several flour mills in Kansas

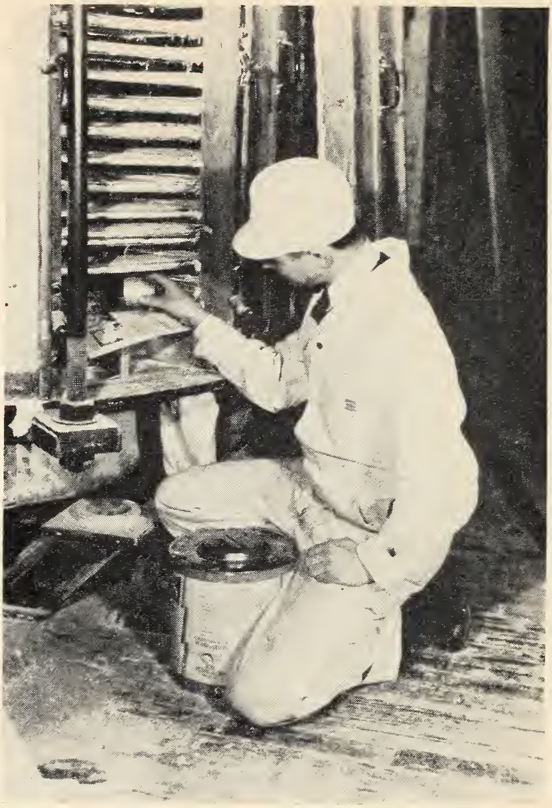

FIGURE 30.—Local fumigation of sifter with calcium cyanide. It is necessary to wear a gas mask when several units are treated at one time.

that represented different types of construction. These demonstrations were so successful that the heat method was thoroughly tested by the Bureau of Entomology, United States Department of Agriculture, and by entomologists in several States in the years immediately following Dean's work, with the result that many flour mills in the United States, Canada, and elsewhere were equipped for using this method. Besides being effective, the heat method has the added advantage of being absolutely safe.

## SUPERHEATING A FLOUR MILL

To destroy the insect populations of a flour mill successfully by superheating, it is necessary to produce temperatures of from 120° to 130° F. in all parts of the mill and maintain them for 10 to 12 hours. Two methods for superheating mills are now in use. When the heat treatment was first developed, the high temperatures were obtained by increasing the number or length of the steam pipes in the mill enough to produce the desired effect. In recent years unit heaters have been developed that require no elaborate piping system, raise the temperature rapidly, and by a forced circulation system keep the heat more uniformly distributed than was possible with the old system.

## Most Effective Time to Heat

With many mills it is essential that advantage be taken of favorable weather conditions, if superheating is to be attempted. High winds and low outside temperatures will prevent satisfactory temperatures from being obtained and held, especially if the mill is of loose construction. It is desirable, therefore, to choose a day when the outdoor temperature is high and when there is little or no wind. With buildings of modern tight construction, outdoor conditions are not so important, particularly if the unit-heater system of superheating is employed.

## Heating Equipment Required

If the wall-radiation system is used, steam heat at a pressure of 25 to 40 pounds per square inch in well-distributed steam pipes is required. It has been found that 1 square foot of radiation surface will heat from 50 to 100 cubic feet of space to the required temperatures, depending on the construction of the building and the number of floors. For a five-story building, 1 square foot of radiation surface is recommended for each 50, 60, 75, and 110 cubic feet of space for the first, second, third, fourth, and fifth floors, respectively. The amount of radiation surface per linear foot and the number of linear feet of pipe required to make 1 square foot of radiation surface for pipes of various sizes are shown in table 1. If steam pipe is used for the radiation, 1¼- or 1½-inch pipe is recommended as most practical.

**Table 1.**—*Radiation surface of steam pipe of different diameters and lengths*

| Size of pipe | Radiating surface per linear foot | Length of pipe per square foot of radiating surface | Size of pipe | Radiating surface per linear foot | Length of pipe per square foot of radiating surface |
|---|---|---|---|---|---|
| | *Square foot* | *Feet* | | *Square foot* | *Feet* |
| 1 inch | 0.346 | 2.9 | 2 inches | 0.622 | 1.6 |
| 1¼ inches | .434 | 2.3 | 2½ inches | .753 | 1.3 |
| 1½ inches | .494 | 2.0 | | | |

Since conditions will vary in each mill, the mill engineer will have to make adjustments until a satisfactory arrangement of the radiation is obtained. Steam pipes should be located near the floor, and traps should be provided to draw off all water accumulating in the pipes and radiators. To keep the air in circulation, fans should be provided on each floor near the radiators, or the machinery should be run at regular intervals.

If unit heaters are used to provide heat, they may be installed permanently on each floor or brought in and connected when required. In these heaters air drawn from near the floor is passed over a series of steam coils and then blown out of large vents at the top of the unit, thus assuring a fairly uniform distribution of heat. A good-sized unit, as shown in figure 31, will supply sufficient heat for 2,500 cubic

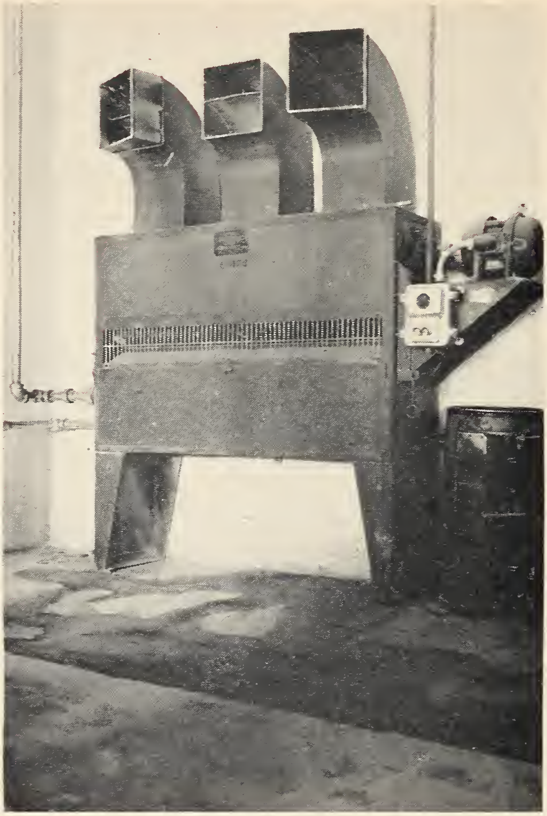

FIGURE 31.—Unit heater installed in a flour mill.

feet and will use approximately 500 pounds of steam per hour. Unit heaters of the size and capacity suited for any particular mill may be obtained from commercial concerns.

## PREPARING THE MILL FOR HEATING

The mill should be allowed to run empty long enough to reduce the stock in the various milling units as much as possible. Elevator boots should be cleaned out and the stock removed for treatment in the fumigation vault or heating chamber. All bagged milled products and accumulations of stock in the mill should be removed, and treated or disposed of. Roof ventilators should be sealed and all windows, doors, ventilators, spouts, or chutes leading outside should be closed. Each floor should be isolated from the others by closing all holes between floors, and by stuffing sacking into spouts. Elevator boots should be left open after cleaning. Belt tighteners should be loosened, and the belts sprayed with neat's-foot oil. Thermometers placed on each floor will indicate when satisfactory temperatures are attained. If a sprinkler system is installed in the mill, the sprinkler heads should be adjusted to prevent their discharge by temperatures lower than 212° F.

## TIME REQUIRED FOR SUPERHEATING

The time required to superheat a mill will, of course, depend on the construction of the mill, the heating capacity of the equipment, and the outside temperature. Each mill is likely to present a different problem. Heat will ordinarily not have to be applied to a modern mill, properly equipped with unit heaters, for more than 20 hours; and by keeping the mill closed for an additional 20 or 24 hours an excellent kill will be obtained. In loosely constructed buildings and in those heated by ordinary steam pipes along the walls, a longer time will be required before temperatures of from 120° to 130° F. are attained in all parts of the mill. The heating should be continued in all cases until these temperatures have been maintained for at least 10 hours.

## EFFECT OF HEAT TREATMENT ON MILL EQUIPMENT

The chief objection to the use of heat for treating the mill is the effect on the machinery. The drying effect of the high temperatures on wooden milling machinery causes warping, cracking, and the opening up of elevator legs, elevator heads, sifters, purifiers, and reels. Tight belts may soften and stretch, and grease melts and escapes from grease cups. An exaggerated idea of the importance of these objectionable features may be obtained when a mill is superheated for the first time. These features soon come to be taken as a matter of course, however, and much of the trouble caused by the warping and cracking of the woodwork can be avoided by keeping the relative humidity from falling below 40 percent. This is accomplished by releasing a little steam on each floor. Containers can be placed under grease cups to catch the melting grease. If the air in the mill is kept in circulation by electric fans, stratification will be prevented and much of the harmful effect caused by high temperatures in certain parts of the mill will be obviated.

## EFFECT OF HEAT ON THE BAKING QUALITY OF THE FLOUR

The degree of heat to which flour is exposed in the process of superheating a mill is not sufficient to exert a deleterious effect on the baking quality. Baking tests made of a patent hard-wheat flour, a low-grade hard-wheat flour, and a pancake flour showed that exposure of the patent and low-grade flours to a temperature of 140° F. for 9 hours, on three different occasions at intervals of 2 and 4 weeks, had no injurious effect, and treatment of the pancake flour for 48 hours at 130° also proved harmless.

## ADDITIONAL TREATMENTS

Records of temperatures obtained in various parts of a mill undergoing superheating indicate that heated air has a tendency to stratify, that it is difficult to obtain a uniform temperature at the floor and ceiling of a room, and that killing temperatures are reached on the upper floors of a mill long before they are reached on the lower floors. These differences in temperature levels are much greater in mills using the wall-radiation system of heating, and it is often difficult and sometimes impossible to obtain satisfactory floor temperatures on the lower floors of the mill without extending the heating period excessively. In such cases it has been found economical to fumigate the lower floors or to apply a spray after the temperature has reached approximately 110° F.

## Cost of Superheating a Mill

The cost of superheating a mill compares favorably with that of fumigation, if the length of time the mill is shut down is not considered. When unit heaters are employed, the shut-down period does not differ greatly from that necessitated by fumigation. The actual cost of treating a mill by heat will usually be less than 25 cents per 1,000 cubic feet of space, although that does not take into consideration interest on the investment and depreciation on the heating equipment.

## A Heating Room or Chamber

A room for sterilizing returned products and used bags by means of heat will be found useful and can be employed in place of a fumigation vault. The vault should be of brick or concrete, designed to avoid the loss of heat. Wall radiation of about 20 square feet per 100 cubic feet of vault space has been found sufficient to supply the proper amount of heat, or a small unit heater can be employed. A false or raised floor should be provided to allow circulation of hot air under the materials to be heated, and racks should be installed for separating bags of flour and other supplies. If wall radiation is used, a fan for circulating and preventing stratification of the heated air is necessary, because without it there may be a difference of as much as 100° F. between floor and ceiling temperatures in a 1,000-cubic-foot vault. The motor operating the fan should be mounted outside the vault to protect it from the heat, unless it is designed for operation in high temperatures.

With a steam pressure of from 50 to 75 pounds, temperatures up to 200° F. can be reached quickly and maintained. With vault temperatures between 180° and 200°, 100-pound bags of feed or flour will be completely freed from insect life in 24 hours. As heat does not penetrate bulk-milled cereals rapidly, it is necessary to separate the bags in the vault by the use of racks.

## Continuous-process Heat Treatment of Milled Cereal Products

Milled cereal products too coarse to be passed through bolting cloth fine enough to remove all insect life must be processed in some other way to ensure their leaving the mill or manufacturing plant free of insects. Continuous-process sterilization by heat has been found most satisfactory and economical and is more commonly used than any other treatment.

Many concerns heat their product to temperatures of 160° F. or even higher in order to be sure of obtaining a complete kill. The important point is to make certain that the product is uniformly heated. Insects may be protected by portions of the material that are underheated. The extreme temperature that can be employed will depend on the product and the use for which it is intended. Flours to be used for raised bread or pastry cannot be subjected to temperatures above 170° F. with safety. Cereal products, however, can stand much higher temperatures. None of the insects that infest milled cereal products can survive exposure to a temperature of 140° for more than 5 minutes; hence, raising the temperature of the product to 140° or slightly higher and maintaining it at that level for about 10 minutes will ensure the death of any insect life that may be present.

Figure 32 illustrates a procedure for heating and cooling a cereal product that, according to Chapman,[5] is highly satisfactory.

There are a number of machines on the market that have been designed for heat-treating milled cereal products, the heat being derived from steam, hot air, or electricity. In many, provision is also made to prevent loss in moisture content of the product during the treatment. To be satisfactory for the purpose, a machine should heat the product uniformly.

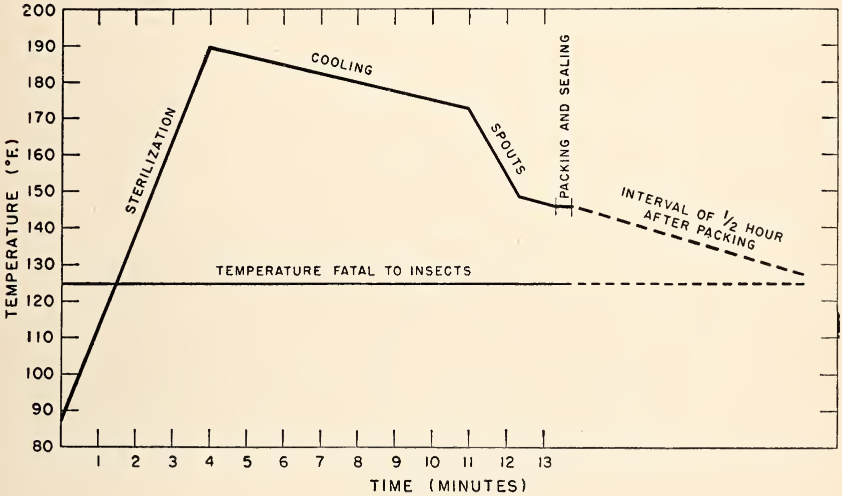

**Figure 32.**—A satisfactory temperature range for cereals during the process of heating and packing. (Chapman.)

Heat-sterilized cereal products should go directly from the sterilizer to the packer to prevent reinfestation before packing. A sterilizer of simple construction consists of a series of steam-jacketed metal cylinders or drums placed horizontally one above another and connected so that corn meal, farina, or other milled cereal products introduced into one end of the top cylinder is conveyed to the other end of the cylinder by a screw conveyor, where it drops into the cylinder below. It is conveyed in a similar manner through the entire series of cylinders. In its passage through the various cylinders the cereal product will be gradually and uniformly heated, until it emerges at the bottom at any desired temperature. With a series of 3 cylinders operating at a steam pressure of 100 pounds, the temperature of a cereal product can be raised to 160° F. in 5 to 6 minutes. The heated product should then be sifted through a 20-wire screen, to remove any material that may have been caked by the heat, and should be packed while still hot. Different combinations of heating cylinders and steam pressures can be used to suit individual situations.

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[5] Chapman, R. N. Insects infesting stored food products. Minn. Agr. Expt. Sta. Bul. 198, 76 pp., illus. 1921.

## SUPPLEMENTARY MEASURES

Notwithstanding all precautions, insects occasionally get by the main bolters and become established in flour conveyers, elevator boots, bleaching machinery, and other equipment between them and the packers. In the modern mill this infestation is not likely to be heavy, but in order to prevent the possibility of any flour being packed out with any stage of insect life in it, some method of treating the flour just before it passes to the packer bin should be employed.

The proper location of machinery used for removing or destroying insect life in finished flour is most important. For maximum efficiency and to prevent the possibility of reinfestation, this machinery should be placed directly over the packer bins. If it is placed before the chlorine agitators in such a manner that an extensive system of conveyers is required to transport the flour to the packer bins, additional opportunity for reinfestation is afforded. Despite the belief of many millers that chlorine gas will kill flour-infesting insects, large colonies of flour beetles have been found breeding in the chlorine agitators themselves.

### Use of Reels and Sifters to Redress Flour

The use of some type of redressing machinery, for the removal of caked flour or foreign material that has been accidentally incorporated in the flour during the process of manufacture is customary in most mills. Formerly this redressing machinery consisted of reels or sifters which, owing to limited bolting surfaces and the need for a high capacity, were equipped with relatively coarse cloth. This removed the foreign matter and the larger forms of insects, but the eggs and small larval forms often passed through with the flour.

The ability of silk bolting cloth of proper fineness to remove all stages of insect life has been definitely established. The eggs and young larvae of different species of flour-infesting insects vary greatly in size, but a 10XX silk bolting cloth can be depended on to remove all stages.

Prior to 1937 nearly all redressing of flour was accomplished with reels. It has been shown, however, that on account of their construction, reels are not the best types of equipment for the work. Conveyors in reels (fig. 33) are so arranged that it is a simple process for insects removed in the redressing process to crawl from the tail-over conveyor to the conveyor handling the finished flour. Sifters, on the other hand, are entirely different in construction. The tail-over and the finished flour are handled by separate slide spouts that have no connection with each other (fig. 34). It is impossible for insects to crawl from one stream to another, and the only way for infestations to pass through with the finished flour is by means of breaks in the cloth or through lack of care during inspection or repair of the sifter sections. The use of sifters covered with 10XX bolting cloth instead of reels is therefore recommended for final redressing of finished flour.

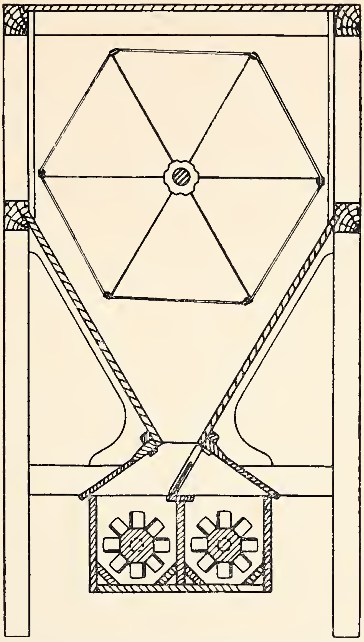

Figure 33.—Cross section of redressing reel, showing close proximity of flour and tail-over conveyers. When heavy infestations are allowed to build up in the tail-over conveyer, insects crawl over into the finished-flour conveyer.

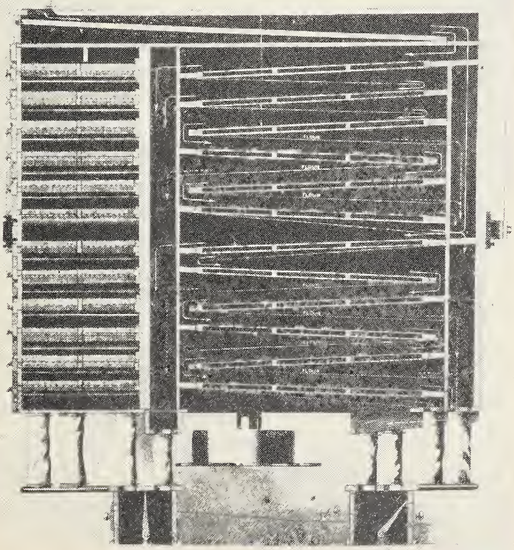

Figure 34.—Cross section of sifter showing complete separation of flour stream from the tail-over stream. There is no possibility of the flour stream becoming infested with insects from the tail-over.

## Treating Flour With Centrifugal Force

A device (fig. 35) using centrifugal force has now been perfected for the destruction of insect life in milled cereal products such as flour. Flour spouted to the machine is hurled by centrifugal force between two flat steel discs or plates that revolve on a central shaft at 3.500 r. p. m. Small, round, hardened-steel posts are closely spaced in two concentric rings between the two discs. The impact of the flour against the revolving discs and posts, and against the housing of the machine, is so great that all insect stages, including the egg, that may be in the flour are killed. The treated flour is carried off through an outlet spout or dropped directly into a bin. Units range in capacity from 10 to 75 barrels of flour per hour. They may be used separately or in conjunction with reels or sifters.

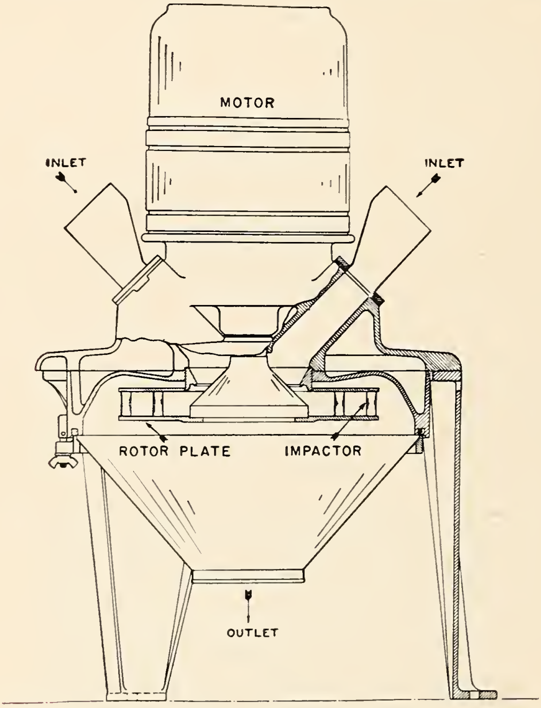

Figure 35.—A mechanical bulk-flour centrifugal machine. (Courtesy of the Safety Car Heating and Lighting Company.)

## Insect Contamination in Flour and Methods of Detecting It

In previous pages it has ben stated that the presence of insect excrement in flour renders it unfit for human consumption. It has been determined, however, that the actual volume of flour produced by a mill, in relation to the insect population present, is so great that the contamination acquired during passage through the mill is extremely small, and examination of the finished flour would reveal insignificant amounts present.

Returned flours, or stocks of clear or low-grade flours, which are to be used in blending operations should first be examined for the presence of insect contamination, otherwise there is the possibility that the resulting blend may be sufficiently contaminated to make it subject to seizure after it enters interstate commerce.

The methods used to detect the presence of insect excrement and insect fragments in flour are simple and can be employed by anyone with the proper equipment. Two different methods have been devised by officials of the United States Food and Drug Administration. One means of detecting the presence of insect excrement in flour is based on the different reactions of flour particles and pellets of excrement when moistened with oil. The flour particles become clear and transparent, whereas the pieces of excrement retain more or less their white, opaque appearance. This test, developed by B. J. Howard,[6] is described briefly as follows:

> One-tenth of a gram of the thoroughly mixed sample is weighed out in a small watch glass (1½ to 2½ inches in diameter). By use of a small scalpel the flour is then spread out in five narrow streaks on a 4- by 5-inch glass plate, and, with a dropping bottle, 3 or 4 drops of mineral oil (or a mixture of equal parts of mineral and olive oil) are distributed along each streak. The oil is mixed by means of a small scalpel with the flour in such a way as to retain the mixture of flour and oil in streaks, if possible not over ⅜ inch wide. This precaution as to narrow streaks makes the examination a simpler proposition. The preparation is then examined by reflected light under a low-power Greenough binocular type of microscope at a magnification of from 20 to 30 diameters, and the insect excreta pellets counted. They stand out distinctly in contrast with the flour particles which have been rendered almost invisible by the oil. The number of pellets is calculated and reported in terms of the number per gram.
>
> No tolerance limits have been established. The characteristic appearance of the excreta left by a number of the common insect pests of stored-food products is shown in figure 36.

A flotation test developed by Kenton L. Harris and W. G. Helsel[7] for determining the presence and quantity of insect fragments and other filth in flour is described as follows:

> Weigh out 50 grams of the well-mixed sample of flour in a 250-cc. beaker and transfer to a 2-liter Wildman trap flask containing 200 cc. of filtered saturated salt (NaCl) solution. The neck of the flask must be dry to prevent flour from sticking. Stir and break up the lumps with the stopper until a homogenous mixture is obtained. . . . Add 3 cc. of gasoline and stir with a gentle rotary motion without tilting the flask. Add salt solution slowly by pouring it down the side of the flask, while the mixture is stirred gently, until the flask is filled sufficiently to permit trapping off the gasoline layer.
>
> Allow the mixture to stand for 30 minutes, stirring 5 or 6 times during this period with a gentle rotary motion to loosen the settled flour without disturbing appreciably the gasoline layer. Make sure that no filth adheres to the side of the flask. Spin the stopper to remove flour from its top and trap off the gasoline layer and about ¼–½ of the water layer by drawing the stopper tightly into the neck of the flask. Transfer the trapped-off material to either a 250-cc. beaker or directly into another trap, rinsing the neck of the flask carefully. . . . The top of the salt solution remaining in the first flask should be examined for visible filth and the contents screened . . . to recover any rodent pellets or lumps of heavy filth which may have settled to the bottom of the flask. If only one Wildman trap is available it should be washed out and the contents of the beaker

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[6] HOWARD, B. J. ESTIMATION OF INSECT EXCRETA IN FLOUR. U. S. Food and Drug Admin. 2 pp. 1939. [Unpublished report.]

[7] HARRIS, K. L., and HELSEL, W. G. METHOD FOR THE RECOVERY OF FILTH FROM FLOUR. U. S. Food and Drug Admin. 4 pp. 1938. [Unpublished report.]

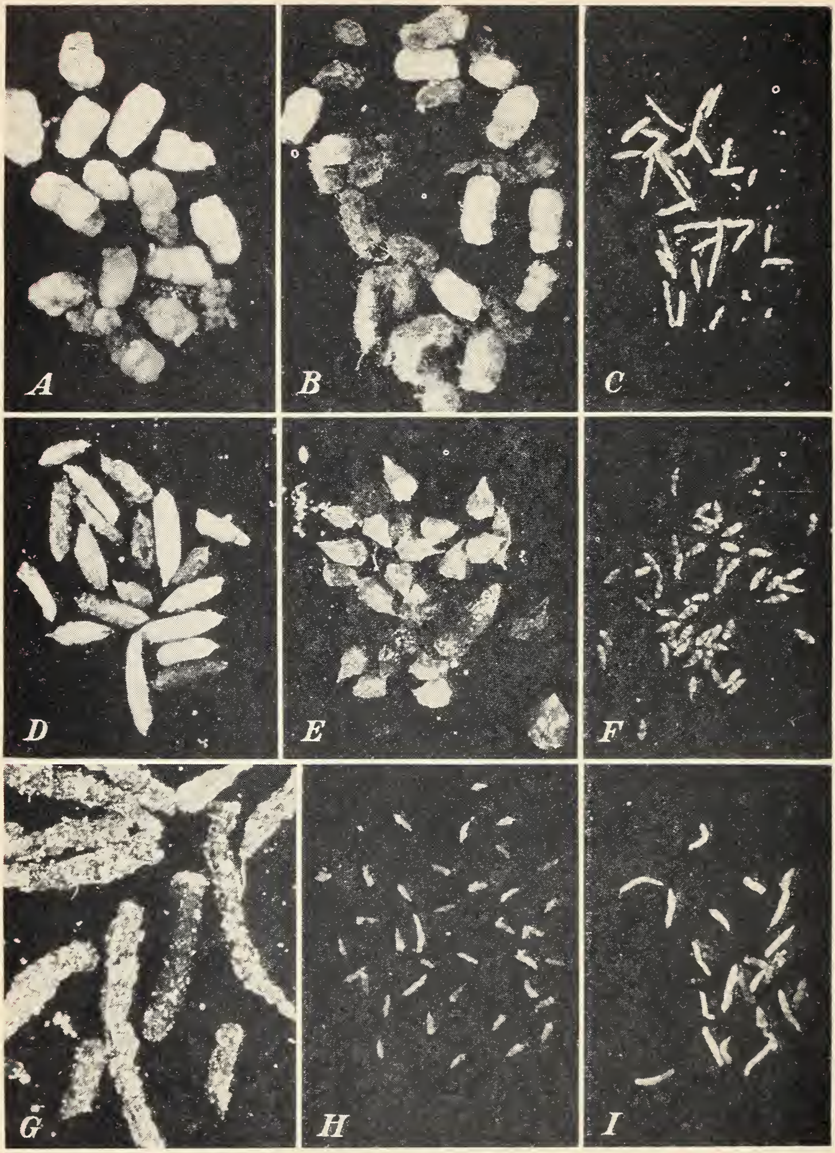

FIGURE 36.—Photographs of insect excrement found in flour (×11). *A*, Indian-meal moth (larva); *B*, Mediterranean flour moth (larva); *C*, confused flour beetle (adult); *D*, cadelle (adult); *E*, cadelle (larva); *F*, saw-tooth grain beetle (adult); *G*, dark mealworm (larva); *H*, lesser grain borer (adult); *I*, rice weevil (adult).

returned to it with careful washing. (For this rewashing of the sample some may find it convenient to use a 1-liter trap.)

To wash the material, the trap into which the gasoline segregation has been placed is filled about three-fourths full of filtered tap water, and the contents stirred rather vigorously to get the gasoline layer down into the water. Finish filling the flask with water, rub and tap the sides with the rubber stopper to bring the gasoline droplets to the top, and allow to stand for 5 minutes. Trap off the gasoline layer and about ½ inch of the water layer as before and filter through a rapid filter paper in a Buckner funnel, rinsing the neck of the flask carefully.

It is usually desirable to wash the filter and sides of the funnel with 95 percent ethyl alcohol to break any emulsion and remove the water from the paper. Remove the filter paper to a petri dish and examine with the aid of a grid under a low-power binocular microscope (approximately 30 ×) with or without clearing with chloral hydrate or mineral oil as desired.

### Insect Control by "Freeze-out" Method

The opening up of mills during periods of subzero weather for the purpose of freeing them from insect life has been practiced to some extent in Northern States for many years and is much practiced in the Prairie Provinces of Canada, where extremely low temperatures can be expected at almost any time during the winter. Most insects that infest flour mills are rather susceptible to low temperatures and, unless protected by heavy accumulations of milled products, are quickly killed if the mill is thrown open and allowed to cool down to outside temperatures during subzero weather.

The "freeze-out" treatment is an inexpensive method of eliminating or reducing insect infestation. It is merely necessary to drain all steam lines and radiators and empty all receptacles containing liquids that will freeze, before opening windows and doors. If mills are equipped with fire barrels, salt can be added to the water to prevent damage from freezing. Accumulations of milling stock or sweepings from the floors of the mill should be removed and elevator boots, located in the basement, cleaned out.

The flour beetles of the genus *Tribolium*, which constitute the greater part of the insect population of a flour mill, are susceptible to cold and can be killed readily in 24 hours by exposure to subzero temperatures. Whenever there is a prospect of 2 or 3 days of subzero weather it would seem well worth while for mill managers to take advantage of the situation by arranging for a "freeze-out" of their mills.

## INSECT CONTROL IN THE WAREHOUSE

### Sanitation

In flour warehouses every precaution should be taken to prevent the development of insect infestation. The floors should be thoroughly swept and all accumulations removed and burned or fumigated in a vault. Freshly milled flour should not be stacked near stocks that have been in the warehouse for any length of time. If separate warehouses are not available for the storing of shorts, bran, and other feed stocks, these materials should be stored in a section well away from those used for flour storage. The older stocks of flour should first be removed as the sales demand.

### Fumigation

Observations indicate that in tight concrete or brick warehouses methyl bromide is an ideal fumigant for the treatment of bagged grain, flour, or feed. The same dosage recommended for mill fumigation will be found adequate unless the warehouse is heavily loaded.

In such cases it may be necessary to increase the dosage to 1½ pounds per 1,000 cubic feet of space. The gas should be applied in the same manner as recommended for the treatment of small mills (fig. 37), and should be circulated for 2 or 3 hours by means of electric fans.

The use of other fumigants for treating grain, flour, and feed warehouses is not recommended as a general practice, except for a general clean-up of rodents or of insects that may be flying or crawling in the open space. The dosages of chloropicrin or hydrocyanic acid used in mill fumigation are excellent for the above purposes but are incapable of penetrating into large piles of bagged milled cereal products. These gases can only reach the center of a pile of bagged grain, flour, or feed by the process of diffusion, and the material in the outside bags absorbs so much of the gas that diffusion to the inner bags is slow.

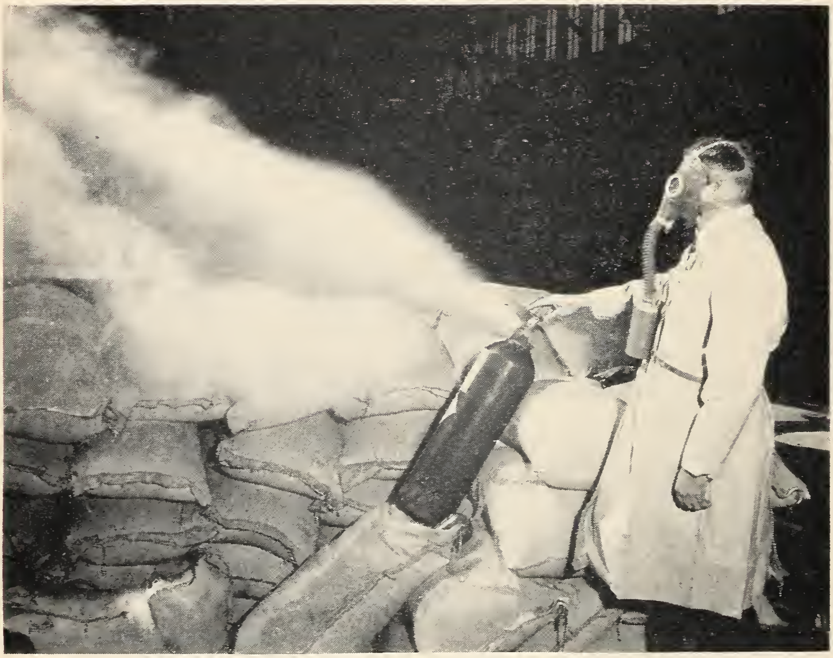

FIGURE 37.—Fumigating a warehouse with methyl bromide.

## ATMOSPHERIC VAULT FUMIGATION

For the treatment of used bags, returned flours, feeds, germ stock, or packaged goods a gastight fumigation chamber or vault, operated at the prevailing atmospheric pressure, can be used to advantage. It may be constructed of any material that can be made gastight. Satisfactory results can be obtained with concrete, brick, hollow tile, or a wooden frame with a sheet-metal lining. The last-named type is popular and in normal times can be constructed at low cost. The simplest form of construction of this type of vault consists of a framework of studding on the outside, with a lining of sheet metal on the inside. The joints between the sheets may be either welded or made tight with asphalt strips. It is desirable to reinforce the metal lining on the outside with a layer of board sheathing. Doors can be of the refrigerator type or of the same type of construction as the walls of the vault. A gasket of canvas-covered live rubber affords a gastight seal. A false floor made of slats should be provided, and an exhaust fan with a ventilating stack leading outside the building housing the vault should be installed. Vaults of brick or hollow tile should have a coating of Keen's cement and one or two coats of paint on the inside.

A plan for a satisfactory vault is shown in figure 38. It can be made of any one of several types of construction and is supplied with a blower for circulating the fumigant in the vault and exhausting the vapors; tubing and spray nozzles for introducing highly volatile fumigants; marine port lights; a thermometer; and a pilot light to indicate when a fumigation is in progress. The blower or exhaust fan can be mounted outside the vault and connected with ducts opening into the vault below the false floor and near the ceiling, as well as into a ventilating stack leading outside the building. By a suitable arrangement of valves the fumigant can be circulated in the vault or exhausted to the outside.

The commodity to be treated is loaded into the vault by hand or moved in on trucks or skids. The door is then closed and the fumigant applied, after which the vault is left locked for the duration of the exposure. At the end of the fumigation the exhaust fan is turned on and allowed to run until the fumes not absorbed by the fumigated commodity have been removed from the vault. While the vault is being unloaded the exhaust fan should be kept running for the protection of the workmen. In some cases auxiliary fans may be required to supply fresh air for the workmen, unless gas masks are worn.

The length of the exposure period will usually depend on circumstances. If there is no urgency a 24-hour exposure, or even longer, should be allowed, because the toxic action of a fumigant is in direct proportion to the length of the exposure. In atmospheric fumigation penetration of bulk-milled cereals is slow.

The temperature of the product to be fumigated is of vital importance. If the product is cold, penetration by fumigants is greatly retarded, sorption of the gas is increased, and much higher dosages are required. With finely milled cereals it is doubtful whether it is practical to attempt atmospheric-vault fumigation at temperatures below 70° F. with fumigants other than methyl bromide.

Circulation of the fumigant in the vault with a fan is advantageous. A bypass from the exhaust fan can be used for the purpose. A duct extending from the fan to a point below the false floor of the vault and similar ducts from the fan to two or three points near the ceiling of the vault will provide a good distribution of the gas.

For applying the fumigant several methods can be used. Liquid fumigants that are not very volatile are usually introduced through a pipe from the outside by gravity or compressed air into shallow evaporating pans fastened inside the vault near the top. Volatile fumigants, such as liquid hydrocyanic acid or methyl bromide, are usually injected through a short piping system with one or more spray

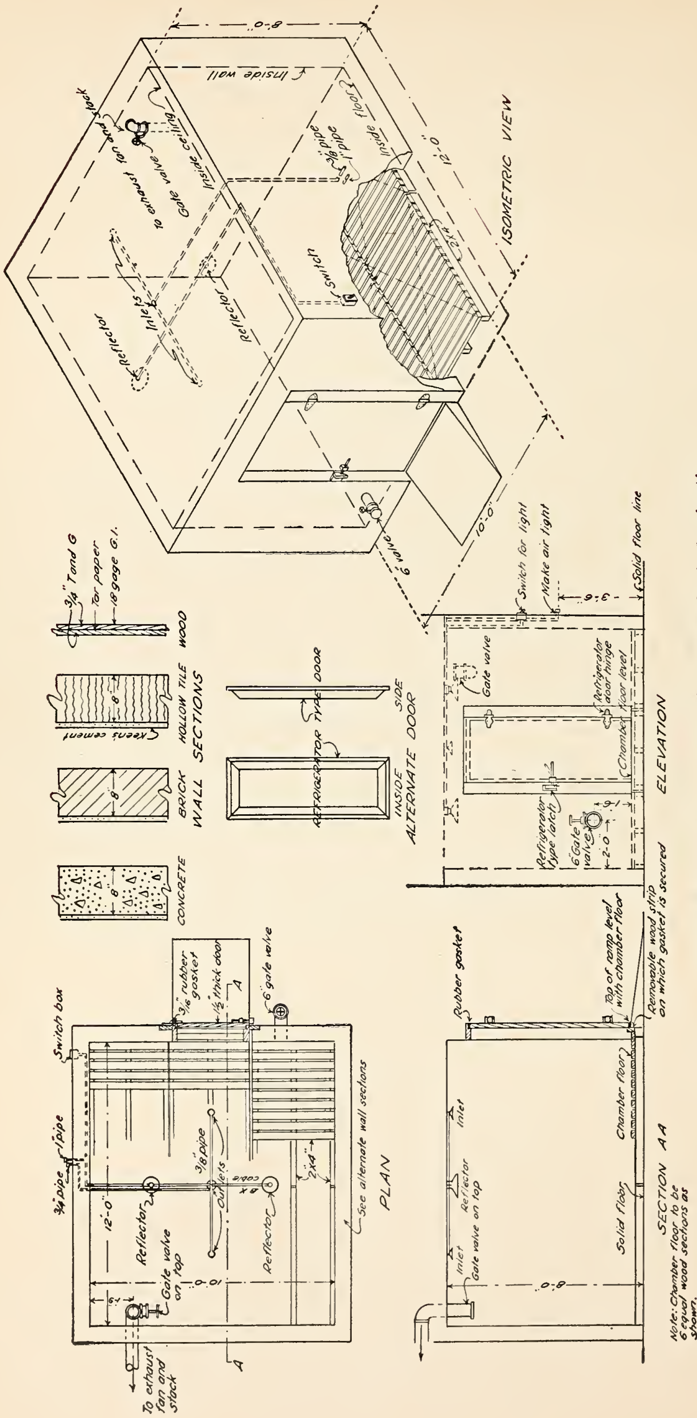

FIGURE 38.—Plan of a vault for atmospheric fumigation.

nozzles. The natural pressure of some gases is sufficient to introduce the dosage required without the use of air pressure. Hydrocyanic acid can be generated for use in atmospheric vaults by any of the methods described for the treatment of mills or warehouses. The method selected will depend on the preference of the fumigator.

The choice of the fumigant to be used will depend on its availability, cost, and suitability for treating the product to be fumigated. The quantity of fumigant to be used will depend on the length of exposure, the temperature and nature of the product, and the size of the load in the vault. If the vault is filled, the dosage can be calculated on its cubic content, otherwise it should be based on the load.

For the treatment of used bags and second-hand mill machinery, the following dosages per 1,000 cubic feet of space are recommended: Methyl bromide, 1 pound; hydrocyanic acid, 1 pound of the liquid HCN or its equivalent; chloropicrin, 1½ pounds; ethylene dichloride-carbon tetrachloride 3–1 mixture, 1½ gallons; ethylene oxide-carbon dioxide 1–9 mixture, 20 pounds; 3–1 ethylene dichloride-carbon tetrachloride mixture plus 10 percent of methyl bromide, 1 gallon.

Bagged flour and feed are more difficult to fumigate successfully, owing to the excessive absorption of the gas by the outer layers of flour or feed. Methyl bromide is most satisfactory for this purpose. The dosage based on a vault more than half full should be 1 pound for the first ton of flour or feed plus 2 ounces for each additional ton. For a full vault the dosage would be approximately 3 pounds per 1,000 cubic feet. Circulation of this gas is necessary.

A dosage of 12 ounces of liquid hydrocyanic acid or its equivalent per ton of flour or feed is satisfactory for a 24-hour exposure with flour or feed at a temperature of 80° F. or above. This is equivalent to a dosage of approximately 10 pounds per 1,000 cubic feet of space in a fully loaded vault. For a fully loaded vault, a dosage of 10 pounds of chloropicrin per 1,000 cubic feet of space is required. For partially filled vaults the dosage can be reduced proportionately.

If railway cars are used instead of atmospheric vaults for the fumigation of second-hand machinery, a dosage per car of 6 pounds of liquid hydrocyanic acid or its equivalent, or 6 pounds of methyl bromide will be found satisfactory.

## VACUUM FUMIGATION

Fumigation by vacuum consists in placing the commodities to be fumigated in a gastight steel chamber, removing the air, and replacing it with a gas lethal to insects. By this method a more rapid penetration of commodities by the gas is obtained than in atmospheric fumigation, and insects are reached and killed with a rapidity that is not obtainable in an atmospheric vault. The length of exposure required in vacuum fumigation ranges from 1 to 3 hours, as compared with from 10 to 24 hours under atmospheric conditions.

In addition to the reduction in time of exposure, vacuum fumigation has several other advantages. At the end of a fumigation the removal of the fumigant from the treated commodities can be speeded up by the process known as "air washing." This consists of drawing a vacuum of 27 inches or more and "breaking" it with air. If this is repeated once or twice the commodities in the fumigation chamber are literally washed with air and much of the fumigant is thereby removed. A further advantage lies in the fact that by this method workmen are not exposed to the danger of entering a vault undergoing fumigation, and the danger from breathing the vapors during the unloading of a vault is lessened.

### THE EQUIPMENT

Either rectangular or cylindrical vacuum chambers (fig. 39), are obtainable. For convenience in loading, rectangular tanks are usually preferred. They are made in many sizes. The size of the chamber chosen will depend on the type and amount of material to be fumigated and the amount of space available for it in the mill or factory.

The tanks are usually set up so that small trucks or factory skids on narrow-gage tracks can be run right into them. In some mills one end of the vacuum tank opens into the receiving room and the other end into the general storage room. Raw materials likely to be infested are then fumigated before they are allowed to go into the general storage room.

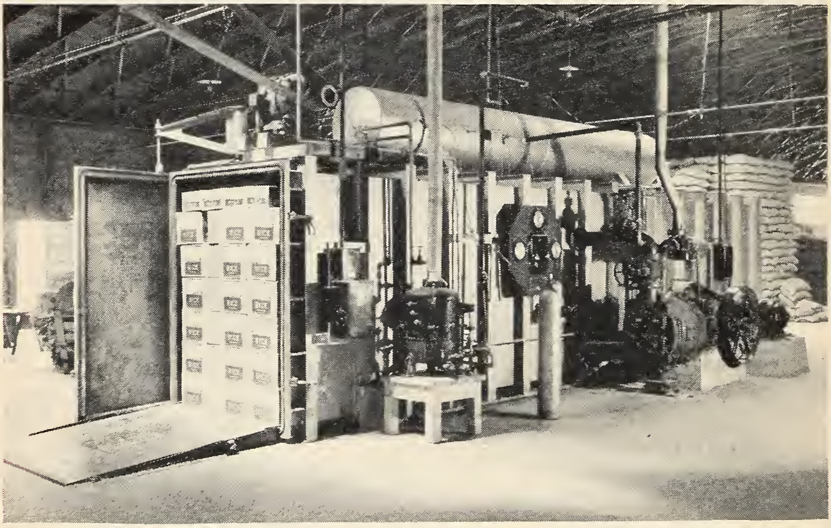

FIGURE 39.—Rectangular vacuum vault. As a safety feature, there should be a guard over the flywheel of the pump.

The doors of the vacuum tank should be so balanced and hung that they can be easily and quickly opened and closed by one man. The gaskets should be durable and at the same time provide a gastight seal. The efficiency of a tank depends largely on the tightness with which the door or doors fit. A well-built tank should hold a vacuum without an appreciable loss during the exposure period.

Many tanks were formerly equipped with steam coils or electric heating units to maintain a favorable temperature during fumigation. Such equipment is of little value, because it is impossible to raise the temperature of the load in the tank rapidly and the fumigant when introduced quickly assumes that of the commodity in the tank.

Each installation requires a vacuum pump capable of pulling a 28-inch vacuum in 10 minutes or less.

The use of a vaporizer in connection with a vacuum chamber adds considerably to its efficiency since it ensures the entrance of the fumigant into the chamber in a gaseous state. The type of vaporizer most commonly used consists of a steel tank in which steam is used to heat the fumigant.

### VACUUM-FUMIGATION METHODS

The commodity to be fumigated is first loaded into the vacuum chamber, the door or doors tightly closed, and the pressure reduced to 2 inches absolute. In terms of vacuum this is equivalent to 28 inches, corrected reading. The fumigant is then admitted through the vaporizer to the vacuum chamber without the addition of air, the resulting pressure being held without change for the duration of the fumigation. Breaking the vacuum down with air, as was formerly practiced, does not aid in the penetration of the commodity to be fumigated, but actually retards it, and the addition of air decreases the insecticidal action of the fumigant.

At the conclusion of the exposure period the gas is pumped out of the chamber and the vacuum then broken with air. If so desired, the fumigated products can be "air washed" several times by alternately drawing and breaking a vacuum of about 27 inches. In some cases this "air washing" is dispensed with, since it has been found that with some gases the fumigant absorbed and retained by the commodity exerts a further insecticidal action, known as post-fumigation, after the material is removed from the tank. When such a procedure is adopted, arrangements must be made to carry off the vapors from the vacuum chamber while it is being unloaded, in order to safeguard the workmen.

### DISTRIBUTION OF THE FUMIGANT IN THE VACUUM CHAMBER

Theoretically, when a fumigant is introduced into a vacuum chamber from which the air has been removed the fumigant should penetrate uniformly to all parts of the chamber. This is what occurs if the tank is empty; however, if the chamber is filled, a uniform distribution of the gas is not obtained. Excessive sorption of the fumigant by the outside layers, and possibly the physical barrier of the load itself, obstruct the passage of the gas, and all portions of the load are not subjected to the same concentration of the fumigant.

It has been found that if, instead of using one orifice for introducing the fumigant, multiple gas inlets are provided along the four longitudinal angles of a rectangular tank, a more uniform distribution of the gas is obtained. Furthermore, by means of a bypass from the exhaust to the multiple gas-inlet system the vacuum pump can be utilized to circulate the gas in the tank, a procedure that aids materially in the distribution of the gas. Experimental evidence has shown that the dosage required to give a kill without circulating the gas can be reduced 25 percent by circulating the gas for 15 minutes after it is introduced into the vacuum tank. There appears to be no advantage in circulating it for a longer period.

### EFFECT OF TEMPERATURE

As with all types of fumigation, temperature is an important factor in vacuum fumigation. The higher the temperature the more favorable it is for fumigation. The temperature of the product to be fumigated is again the controlling factor. Insects infesting the commodity have approximately the same temperature as the commodity itself, and the fumigant also will quickly assume the temperature of the load, after it is introduced into the tank.

Much higher dosages are required for the successful fumigation of cold commodities, and it is impractical to attempt to fumigate milled cereals if cold, since the dosages required are too great. Cold commodities should be allowed to warm up, at least to normal room temperatures, before fumigation.

### COMPUTING THE DOSAGE

The dosage will, of course, vary with the fumigant used, the length of the exposure, the type and quantity of the commodity to be treated, and the temperature of the commodity. To ensure satisfactory results, all these factors must be taken into consideration. It has been determined that the sorption of fumigants differs both with the fumigant and the commodity, but that it is in proportion to the quantity of the commodity treated. It is therefore more economical, if the tank is half full or more, to calculate the dosage on the basis of the load rather than on the cubic content of the tank. If desirable, however, the dosage can be computed according to the cubic content of the tank, on the basis of a full load.

### MEASURING THE DOSAGE

The dosage may be measured by weighing it into the vacuum tank or vaporizer, by measuring it volumetrically, or by dropping the vacuum a given number of inches by injection of the fumigant. The first two methods are accurate. The third method cannot be used indiscriminately, because with a given quantity of gas the drop in vacuum will vary with the quantity and type of commodity being fumigated and with the temperature of the gas or the commodity in the tank, i. e., the space occupied by a gas varies with its temperature—gas absorbed by the commodity would not cause a change in the pressure or in the reading of the vacuum gage. It is a convenient method, however, for commercial use, and by making the proper allowance for differences in temperature and in the type and quantity of the load in the tank, the dosage can be measured in this way with sufficient accuracy for ordinary work.

### FUMIGANTS USED IN VACUUM

Most of the fumigants recommended for use in atmospheric vaults can also be used in vacuum chambers, although in general only the more toxic fumigants are used commercially. For the fumigation of bagged flour or feed the following dosages are recommended: Methyl bromide, 4 pounds per 1,000 cubic feet for 3 hours or 3 pounds per 1,000 cubic feet for 15 hours; liquid hydrocyanic acid, 2 pounds per 1,000 cubic feet, or 2 ounces per ton of product in a filled vault, for 3 hours with a temperature of 85° F. or above; ethylene oxide-carbon dioxide (1–9 mixture), 60 pounds per 1,000 cubic feet, or 4 pounds per ton of product, for 6 hours, or 45 pounds per 1,000 cubic feet, or 3 pounds per ton of product, for 15 hours with a flour or feed temperature of 85° F. or above.

### FUMIGATION UNDER A TARPAULIN

If tight warehouses or fumigating vaults are not available, it is possible to fumigate stacks of bagged flour or feeds by the use of a tarpaulin of rubberized or plastic-treated canvas. The material to be fumigated is stacked to a height of 5 or 6 feet, allowing for complete coverage by the tarpaulin with a margin of about 2 feet on all sides (fig. 40). The edges of the tarpaulin should be weighted down carefully by a row of filled bags placed all around the stack so as to prevent leakage of the gas from around its base. Provision is made for an air dome on top of the stack by using two bags placed edgewise about 4 feet apart on top of the stack. This air dome will provide free space to permit downward diffusion of the gas, which is introduced into the tarpaulin-covered stack through a copper tube leading to the air dome. Methyl bromide is the most satisfactory fumigant to use for this type of treatment. The dosage, which should be the same as recommended for vault fumigation, can be measured in by use of a special applicator attached to the cylinder, or weighed in by placing the cylinder on a scale platform. In some cases it may be found convenient to use 1-pound cans instead of a cylinder. A special can puncturer can be attached to the copper tube so that the proper number of cans required can be placed in the puncturing device, one at a time, and allowed to empty themselves through the tube.

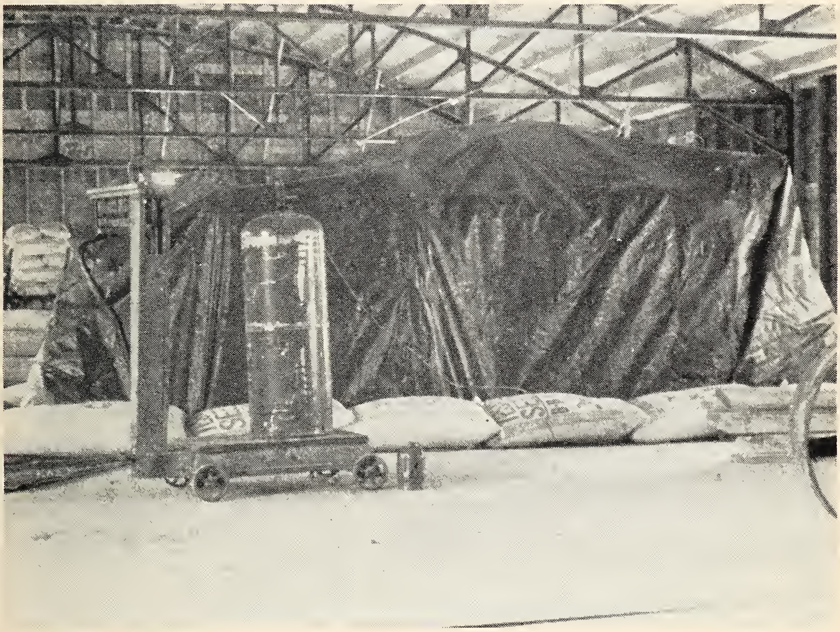

FIGURE 40.—Stack of bags covered with tarpaulin ready for fumigation.

This method of fumigation should be conducted outdoors, and only where there will be no danger of workmen being exposed to the fumes that might escape from the stack. An outdoor loading platform, pier, or similar unconfined space is preferable. At the expiration of a 16- to 24-hour fumigation period the tarpaulin should be partially pulled back from the fumigated material and the stack allowed to air for at least 30 minutes before the tarpaulin is entirely removed. Workmen performing the fumigation should be equipped with suitable gas masks, as recommended for fumigation in an atmospheric vault.

## PROTECTING THE FLOUR AFTER MANUFACTURE

The responsibilities of the miller do not cease with the production of an insect-free product. The flour must reach the consumer in perfect condition or the reputation of the miller will suffer. Unless the product is properly packaged, and protected from insect attack in storage and transit, much of the effort expended in the manufacture of a clean product may be wasted.

### Insect-proof Bags

Fabric bags do not protect flour from infestation by insects. Small forms readily crawl through the meshes or through needle holes, and adult insects thrust their ovipositors through the fabric and lay their eggs in the flour. It is of course impracticable to do away with fabric bags entirely, but in many cases paper bags can be substituted. Paper bags afford considerable protection to flour from outside infestation if they are properly made and sealed. With the exception of the cadelle and the lesser grain borer, most flour-infesting insects are unable to cut through the walls of substantial paper bags. They can and do, however, enter through the needle holes where the bags are sewed, unless the holes are protected in some way. All seams of paper bags should be cemented, and sewed tops should be protected by strips of gummed tape or other covering.

### Infestation in the Mill Warehouse

In order to meet the demands of the trade, it is necessary for the flour miller to keep adequate stocks of the different grades of flour. Warehouse space must be provided and proper precautions taken to prevent contamination of flour stocks during the brief or extended periods of storage required.

Infestations of flour stocks in mill warehouses occur all too frequently and may originate from a number of different sources. Eggs or small larvae of flour beetles may be packed with the flour, if it is not properly redressed or if it becomes contaminated between the redressing machinery and the packer. Temporary storage near bran, shorts, screenings, or overs from redress machinery may result in insects crawling from these products to the freshly milled flour. Temporary storage in the warehouse of returned infested flour stocks or of stocks purchased for blending purposes may account for the spread of infestation to clean stock. Insects find hiding places in the woodwork of floors, walls, and dunnage, and fresh flour is often invaded by large numbers of insects from such sources. Insects may also fly in from nearby elevators or other grain-storage structures.

The ideal flour warehouses should be of concrete, stone, or brick, with concrete floors, which can be readily cleaned and will not provide any place in which insects can hide and breed. Care should be taken to see that only properly redressed flour free from insect infestation is placed in storage. No feed, screenings, returned flour stocks, second-hand flour bags, or other material that might be infested, should be stored in flour warehouses, even temporarily. Broken or damaged bags of flour should be stored separately and disposed of quickly. The storage of bagged flour on lift platforms is desirable when such equipment is available, as it will keep it off the floor and facilitate the removal of accumulations therefrom. Strict sanitary measures should be practiced, no dust or accumulations of flour being allowed to remain. Flour stocks should be kept as low as possible and all old stocks disposed of before new lots are touched. After a stack of bagged flour is disposed of, the section of the floor from which it was removed should be thoroughly swept and, if necessary, sprayed. An occasional fumigation with methyl bromide will be found effective in destroying all insect life present, if the warehouse is of tight brick, stone, or concrete construction. If the construction is not of this type but can be made reasonably tight, a general fumigation with hydrocyanic acid or chloropicrin will clean up infestations in the open spaces around the stocks of flour.

## Infestation in Transit

Flour products leaving the mill or warehouse do not usually go directly to the consumer, but must be transported by truck or railway car to bakeries, other warehouses, or grocery stores for distribution. During this period of transit it is subject to invasion by insects. Studies have shown that the railway cars used to transport flour have in many cases also been used to carry grain during the rush of the grain-harvesting season. The ordinary car is so constructed that waste grain, grain dust, or milled cereal products become lodged in cracks and crevices in the woodwork and behind grain linings. Consequently, insect infestations that are difficult to eradicate entirely by ordinary clean-up methods become established in these cars used to carry grain. As soon as fresh flour is placed in infested cars, the insects are attracted to it. They crawl over the bags, thrust eggs through the mesh of fabric bags, and enter them wherever they can.

The time of greatest danger from infestation in transit is during the summer after the cars have been used for carrying grain or feed. At this time, also, large numbers of insects of many kinds, including species that infest grain and flour, are in flight and enter the cars before or during loading operations. Lights used in loading cars may also attract many insects and, although they may not be important pests of stored flour, their presence is annoying and often causes cars to be rejected on arrival at destination.

Steel cars can be effectively fumigated, but wooden cars are not well adapted for this type of treatment. As a routine procedure, it is probably too expensive to be practical. Blowing them out with a jet of compressed air is probably the most effective and economical method of cleaning cars before loading, although the present construction of railway cars makes it difficult to reach all accumulations of grain and milled cereals. Spraying with contact insecticides is probably of some value, but cannot be relied on to eliminate all insects. Lining the cars with heavy Kraft paper will aid materially in protecting the flour during short hauls. The paper acts as a temporary barrier that is effective for short periods, even in heavily infested cars.

Mills experiencing difficulty with insects in flour shipments during July and August may find it advantageous to fumigate the cars after loading with methyl bromide at the rate of 6 pounds per car. This will take care of any insects crawling around the car or that may have flown in during loading operations.

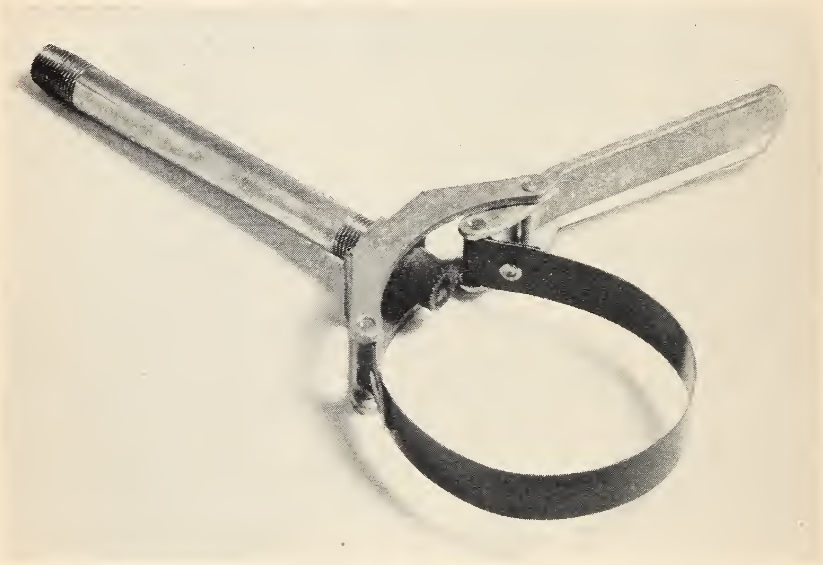

FIGURE 41.—Special can opener for discharging methyl bromide for 1-pound cans.

Loaded cars arriving at their destination in an infested condition can be fumigated successfully with methyl bromide at a dosage of 10 pounds per car (about 3 pounds per 1,000 cubic feet) for an exposure period of from 12 to 18 hours. With exceptionally tight cars this dosage can be reduced to 6 pounds.

Before applying the gas the doors should be sealed with masking tape to prevent leakage. The methyl bromide should be applied from the outside of the car through plastic or copper tubing inserted to a point above the load at the center of the car. If 1-pound cans are used, a can-puncturing device (fig. 41) can be attached to the tubing and the requisite number of cans clamped to the device in succession. The clamp, which should be placed around the can near the bottom, forces the sharpened end of the tubing into the can, from which the fumigant is discharged in less than 1 minute. If cylinders are used, the tubing can be connected to an applicator attached to the cylinder so that the proper amount can be measured out.

Otherwise the tubing can be connected directly to the cylinder and the dosage weighed in. After the exposure period the car should be opened and allowed to aerate for an hour or two before it is unloaded.

Railway companies use strenuous efforts to provide cars free from insect infestation and most of the cars supplied by them for flour shipments are in excellent condition. As a matter of principle, the shipper should examine all cars before loading, and if a car is found to be in poor condition, it should be either rejected or reconditioned by appropriate cleaning methods.

## Infestation in Jobbers' and Wholesale Grocers' Warehouses

Flour is stored for varying periods in the warehouse of jobbers or in wholesale groceries, awaiting distribution. This is often a critical period for flour products, particularly in the Southern States, where temperature and humidity favor the rapid development of insects. Unfortunately, flour is not always stored under the best of conditions. In warehouses with wooden floors and that have long been used for storing milled cereal products, cracks between the floor boards become filled with accumulations of dust, flour, and meal in which countless numbers of insects may breed. These insects are likely to migrate to newly stored lots of flour. The custom of storing many other susceptible food materials, especially returned infested products, alongside of or in the same warehouse with flour is exceedingly common. Needless to say, it is difficult to prevent insects from leaving these products and crawling or flying to fresh stocks of flour. The recommendations suggested for the care of flour stocks in the mill warehouse will apply equally well in the case of the jobber or wholesale grocer.

## Flour Blending at Wholesale Groceries

Many wholesale groceries maintain flour-blending equipment for mixing salt, phosphate, and soda with the flour to make a self-rising flour for local consumption. The flour used for the purpose is often infested by the time it is mixed and, although it is sifted at the time, the screen used is rarely finer than a No. 20 wire. This screen is fine enough to remove adult insects, large lumps of flour, or other large pieces of foreign matter but is not fine enough to remove eggs or young larvae of the flour beetle. Consequently, a certain percentage of the flour produced is infested and will develop a heavy infestation if kept on hand any length of time.

Wholesale grocery companies engaged in this business should use only flour of good grade obtained from a modern mill. Overlong storage should be avoided, and at mixing time the flour should be sifted through a screen fine enough to remove all insect life, or it should be run through a centrifugal machine after being screened.

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